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—OF THE—

American Ceramic Society

A Monthly Journal devoted to the Arts and Sciences Related to the Silicate Industries

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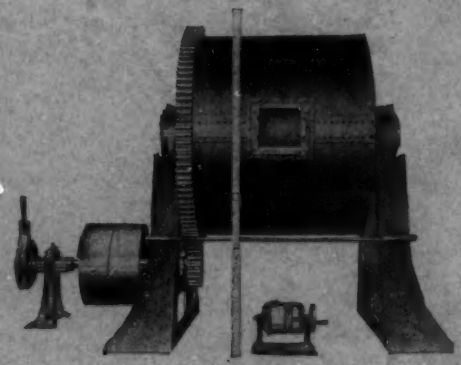

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Vol. 4 **February, 1921** **No. 2**

EDITORIAL

CERAMIC ABSTRACTS

Beginning with the literature of the year, 1921, the Journal will endeavor to extend the scope of its Abstract Division so as to cover all the literature of the world which contains material of direct interest to the ceramic industries. Through the work of our own corps of abstractors supplemented by coöperative arrangements with other abstract journals we hope to make the Abstract Division of the Journal an exhaustive summary of the world's ceramic literature.

If a sufficient number are interested, the Journal is also prepared to offer, at cost, to members of the Society, a special Abstract Reprint Service which will enable members of the Society to assemble and keep up to date a card catalogue of any ceramic subject in which they are specially interested. This service will take the form of supplying monthly reprints, in duplicate (if printed on both sides of the paper) or singly (if printed on one side only), of the abstract division of each number of the Journal. The desired abstracts can thus be clipped and pasted upon cards of any desired size.

It is estimated that this service could be given at a cost of $3.50 per year to each of 50 subscribers and $2.50 per year to each of 100 subscribers. Members interested in securing this service are requested to communicate with the editor not later than March 20. The service would begin with the February Journal and would thus include abstracts of all papers beginning with the year 1921.

Beginning with the present number, each original paper published in the Journal will be preceded by an analytical abstract prepared in accordance with a system devised by G. S. Fulcher of the Corning Glass Works. The abstracts of the papers appearing in the February, March, and April numbers of the Journal will be made by Dr. Fulcher, in order to serve as examples of this system of abstracting. Thereafter, it is hoped that authors of original papers will prepare their own abstracts. An explanatory description of the analytical system of preparing abstracts will be published in an early number of the Journal. These abstracts will take the place of the customary authors' summaries and they will be included in the proposed Abstract Reprint Service, if there should be sufficient demand for that service to justify starting it.

ORIGINAL PAPERS AND DISCUSSIONS

ANCIENT AND MODERN METHODS OF GLASS MANUFACTURE*

By H. L. Dixon

ABSTRACT

Progress in appliances and methods of glass manufacture since 1877.—The article contains a brief summary of the personal experiences and observations of one who for over forty years has actively participated in the development of appliances and methods used in various branches of the glass industry.

It must not be supposed, because of the subject of this paper, that it is necessary or that it is the intention of the writer to review the glass business and its methods of manufacture from the time of its discovery. That would indeed be tiresome and unprofitable, because there are many publications in which the discovery and ancient history of glass manufacture may be read. It is intended only to cover the personal experiences and observation of the writer for a period of a little over forty years of actual participation in the development and improvement of the appliances and methods used in the various branches of the glass industry. A careful comparison of the equipment and processes in vogue during that period will amply justify the use of the word ancient in the title.

In reviewing the progress made in the development of the various appliances and methods employed in the manufacture of glass, it is difficult to avoid indulging in personalities and the mention of many eminent men, leaders in the promotion of the industry, some of whom are still living, and, inasmuch as this is intended to be a review of the improvement in methods of manu-

* Read at the meeting of the Society in Philadelphia, Feb. 23, 1920.

facture rather than a history of the business, it will be impossible to mention a great many of the prominent and capable men deserving of a permanent record in the history of the glass business. In the preparation of a full and complete record of development and improvement in the equipment and processes employed during this period, the difficulty encountered is not the discovery and recital of sufficient crucial and epoch making discoveries that are of interest today, but rather the impossibility of covering the subject completely in the brief manner necessary to avoid being too voluminous and tiresome.

Making Glasshouse Refractories in Early Times

The writer began his business career in 1877 with his father and uncle and one or two others composing the old firm of Thomas Coffin & Company, which had started in business in 1860 as manufacturers of glasshouse pots, furnace blocks and other refractory materials required by the glass trade of that time. This company was the only one engaged in that line of business, but it was the habit of many of the glass manufacturers of those days to make their own pots and refractory materials. Even then the elder members of this company were invariably consulted about the proper dimensions and construction of glasshouse furnaces, of which they had an expert knowledge acquired from a long experience. There was, however, at that time, no such business as furnace building. Thomas Coffin & Company manufactured all of the furnace blocks the trade required in a room 40 by 60 feet in size and had only one kiln, 16 by 18 feet, in which to burn them. It was the custom of glass manufacturers in those days either to manufacture their own furnace material or to purchase it from this company and then employ two or three of the expert furnace builders, bricklayers of exceptional ability, to do the construction work. Plans and specifications for such work were absolutely unknown, it being the habit to copy some other successful furnace and leave all of the details of construction to the brick mason, after obtaining some advice as to the proper diameter, spring of crown arch, size of the eye or fire box, etc. It was the custom in those days for the pot manufacturer, with a sufficient number of men, to deliver the pots to the glass factory,

place them in proper position in the furnace for preheating or in the pot arch as desired. Participation in this work brought the writer in contact with many of the older manufacturers of that day and gave excellent opportunity for observation. It is a delight and satisfaction now to recall how these real pioneers in the glass industry delighted to explain all of the intricacies of the glass business, including the operation of furnaces, and incidentally to recite how much better they were doing, how much more glass they were melting, than their competitors—a valuable school of instruction for a young man, scarcely appreciated at that time but which today is the source of many fond recollections of eminent and capable men of their time who have long since passed away, and which was the source of much profit in the development of after years.

Early Direct Fired Furnaces

The direct firing type of coal burning furnaces was universally used in those days and, because of the splendid fuel obtainable at a very low cost, there was very little inducement for the investment of capital in fuel saving furnaces. All flint or crystal, both lime glass and lead glass, was melted in covered pots in circular furnaces having a fire place or eye in the center. Many of these were teased, or stoked, through a tease hole in one of the pillars between the pots, from the glass factory floor. Afterwards an improvement was made by the design of a furnace in which the fuel could be pushed from the cave or basement into the eye of the furnace, and afterwards this was still further improved by the use of what was known as the bucket teaser. This was a mechanical device that was placed in the cave or basement immediately below the eye of the furnace. It was charged with coal and by means of gears and mechanical contrivances the coal was pushed up through the center of the fire bed, the grate in that case surrounding the bucket. This proved to be a very efficient, hot running furnace and came into use about 1878.

These furnaces were built of clay blocks for the pillars and crown, similar to those in use today; the eye was lined with burnt blocks of large dimensions, and the benches or sieges were made of bulk clay, similar to that in use at the present time. The

flues were distributed around the outside of the circle, passing through the breastwalls in front of the pots and up into the cone or chimney, over the furnace which supplied the draft necessary for the operation of the furnace.

Late in the seventies John Nicholson, Jr. introduced what was known as the Nicholson gas furnace, which was a modification of a French invention, by erecting one of this type at the works of the Rochester Tumbler Company, Rochester, Penna., and this proved to be a marked improvement over the ordinary type of furnace. It was particularly designed to use a cheap grade of fuel—fine slack coal—by converting it into gas and providing means for its complete combustion in the eye of the furnace. This furnace employed three of the old type Siemens natural draft producers located in the basement of the factory, in which the well known restricted grate area of the original Siemens producer was employed, and the fuel was fed through hoppers on the top of the producers. A continuous distillation of gas was obtained which passed through horizontal flues leading to the eye of the furnace, and the air utilized for its combustion was conducted around the walls of the producers and flues as well as the lining of the furnace eye, finally entering the eye near the bench level, where it met the gas from the producers and an approximately perfect combustion was obtained. The results were very economical, in that a saving in cost of coal was effected, and the temperature of the furnace was maintained more uniformly and at a higher degree, so that the production was materially increased. This furnace became very popular and a large number of them were constructed in the ten or twelve years following this first development.

About the same time, in the late seventies, Mr. J. J. Gill of Steubenville, Ohio, introduced what was afterwards known as the Gill furnace, which was an improvement and modification of the Boetius furnace used in Europe. This furnace was also designed particularly to use a cheap grade of coal—fine slack coal—and employed two producers of rather large dimensions, one on each side of the eye of the furnace in the basement or cave immediately under the bench, the coal being fired through tease hole doors in the front walls. The gas distilled from the coal in these producers

passed directly through apertures or ports in the back walls of the producers into the eye. The air for combustion was passed around the walls and crown arches of the producers, as well as around the walls of the eye, becoming heated by induction and absorption and finally being introduced into the eye just above the gas ports below the level of the siege or bench. This proved to be a great improvement over the old type of direct fired furnace and resulted in an increased production because of a higher and more uniform temperature, as well as a reduction in the melting cost because of cheaper fuel.

In the early eighties what is known as the deep eye furnace was developed in New Jersey and was particularly adaptable for the use of the semi-bituminous Georges Creek and Cumberland coals commonly used in that district. This consisted simply of an eye of greater depth than usual for use in flint glass furnaces in which the fuel bed was far enough below the level of the bench or siege to permit the introduction of a secondary supply of air above the fuel bed and in close proximity to the level of the bench, to accomplish the combustion of the volatile gases escaping from the fuel bed below. This was generally operated in a manner similar to the operation of a gas producer for the purpose of liberating the volatile matter and burning it above where it came in contact with the air entering a circular series of ports around the eye, after having been conducted around the walls of the fire bed absorbing such heat as it may by induction through the walls of the eye. This proved to be a very economical fuel burner and one that some manufacturers thought was as effective and economical as either a Gill or Nicholson furnace. This deep eye type of furnace was used extensively in the western bituminous coal district and is in use today in a number of factories where natural gas is not available, and where suitable coal is obtainable within a reasonable cost.

Expansion of the Glasshouse Refractories Business

Owing to the large number of deep eye, Gill and Nicholson furnaces erected within a comparatively few years, the demand for furnace blocks of good quality and special shapes was very much

increased, and necessitated a very large addition to the capacity of the block manufacturers.

In 1878 and 1879 there was an unusual boom in the glass manufacturing industry, especially in tableware and all lines of flint glassware. Idle furnaces were put into operation and new ones were constructed, with the result that the one pot manufacturing company existing at that time could not supply the pots and sufficient of the refractory materials demanded by the suddenly increased business. This led to the organization of the Pittsburgh Clay Pot Company by a number of the glass manufacturers who, for the first time, realized the risk, uncertainty if not danger, of depending upon the one company for their supply of these materials. Since that time the great increase in the business of manufacturing glasshouse pots, furnace blocks and other refractory materials is well known, and it has become one of the largest industries in the country. Glass manufacturers, as a rule, have entirely abandoned the manufacture of these supplies for themselves and depend upon the various institutions engaged in that business for their requirements.

Early Types of Pot Furnaces

In the seventies all window glass and green and amber bottle glass was made in open pot furnaces of the most primitive, direct firing type. They consisted of a square, or rectangular furnace chamber, erected over a cave or basement, the grate extending the full length of the furnace and discharging its ashes into this cave, which was also arranged to supply the air passing through the grate for combustion. The furnaces in the Pittsburgh district, which embraced quite a wide area, in those days were all built of sand stone obtained from quarries at Perryopolis, Pa. The benches or sieges were made of two layers of great slabs of sandstone, provided with wide open joints for expansion. The walls and crown arch were built entirely of the sandstone; the arch being so constructed that, while it was fully 12 inch in thickness, the stones only had a bearing of about 4 inch on the top and an open joint on the bottom of 3 to $3^1/_2$ inches to provide for expansion, the arch having to rise to such an extent that the lower joints would come together and close after the furnace was heated.

It was the custom in those days for the Porter Brothers at Perryopolis to quarry and cut the stone for all of these furnaces during the period of furnace operation, and ship them so they would arrive in time for the construction of the furnaces during July and August of each year, when all glasshouse operations ceased for a period of at least two months. Porter Brothers, during that time, would erect the various furnaces and have them ready for operation in September, there being no clay material employed except the outside casing to back up the stone lining of the furnace walls. In other districts, such as New Jersey and New York, it was the custom to build the furnaces of unburned clay blocks of a mixture of Jersey sand and German pot clay, and frequently they were simply pounded over a wooden form while the clay was in a plastic state, being cut with a wire into sections to take care of the shrinkage and avoid cracking as much as possible. Many of these furnaces were not provided with any stacks but were constructed in the center of a building with a very high conical shaped roof with a cupola at the top. When the melt was being made all doors and windows were closed so that the draft would pull through the cave or tunnel beneath the furnace, through the grate, and out through the ringholes or flues of the furnace, up through the cavity formed by the high roof. Naturally, this method of firing resulted in an enormous loss of fuel and much smoke and soot. The firing of the coal was through the ends of the furnace and the very best grades of lump coal were used. In New Jersey and some other sections they used furnaces with a forced draft which enabled them to use the semi-bituminous coal of the Georges Creek and Cumberland districts, instead of the highly bituminous gas coal of western Pennsylvania.

Previous to 1880 very little had been accomplished in the introduction and application of fuel saving devices for the obvious reason that the best of fuel in most of the glass manufacturing localities was obtainable at a very low price. Of course, various attempts have been made to operate furnaces that would use the cheap grade of fuel, known as slack coal, which at that time was a drug on the market and was obtainable in abundance at the bare cost of mining and delivery. The Nicholson, Gill and deep eye

furnaces were particularly adaptable for the use of this cheap coal; but, while they reduced the cost by using cheaper fuel, they did not reduce the quantity required in a given time, nor did they in any way reduce the labor or skill required in the operation of direct fired coal furnaces.

Introduction of Regenerative Pot Furnaces

Although the well-known Siemens regenerative type of gas furnace had first been applied to the glass manufacturing business in England in 1861, it was not until many years after that it was made use of by the manufacturers of the United States. According to the United States Census Report of 1880 the Division of Glass Manufacture by Joseph D. Weeks, published in 1884, gives the number of Siemens regenerative pot furnaces in operation in 1879 as follows: Great Britain 12, France 22, Belgium 6, all other countries 31. The above covered plate glass, window glass, bottle glass and flint glass manufacturers. Siemens furnaces with daily melting tanks: Great Britain 6. Siemens furnaces with continuous melting tanks: Great Britain 4, France 10, Belgium 1, other countries 3.

It can be seen from this report that, while the Siemens regenerative principle had been extensively applied to the iron and steel business, it had not been adopted by many of the glass manufacturers. In 1866 or 1867 the first Siemens regenerative furnace was applied to the glass business in the United States. This was erected by the engineers of Sir William Siemens, the inventor of this type of furnace, at the O'Hara Glass Works of James B. Lyons & Company on 30th Street in Pittsburgh. It proved to be a failure because of the wrong application of the producer gas to the furnace chamber. At that time the old type of natural draft producer was used in connection with the long cooling tube supposed by the Siemens engineers to be necessary, and the air and gas ports were so constructed that the flame was introduced into the furnace chamber in a horizontal direction above the level of the pots. Great difficulty was experienced in keeping the furnace supplied with gas from the producer because of the accumulation of soot in the cooling tube and flues leading to the furnace. In the application of this principle to the iron and steel

furnaces, this trouble was not considered serious, because they could stop at any time between melts or between heats and remove the soot from the cooling tube and other flues, but in a glass melting furnace where pots were employed this would result in damage to the pots and it was necessary to maintain a continuous supply of gas to preserve a uniform temperature in the furnace that would safeguard the pots. The other difficulty, and the one that was most fatal to the successful operation of this furnace, was the fact that the intense heat of the flame above the pots destroyed them by melting in the crowns, so that it was impossible to maintain a melting temperature and at the same time preserve the pots. While it was not realized at that time, it subsequently became apparent that to operate with such a furnace it was necessary to employ the well known reverberatory principle where the fuel was introduced vertically through the bench or siege in the middle of the furnace within the circle of pots, so that the force of the flame and intense heat would be spent against the crown arch of the furnace and rebound in such a way as to surround the pots and heat them without injury. Inasmuch as this was not understood at that time, this furnace, after a little over one year of operation, was abandoned and the entire equipment torn out for the purpose of restoring the old type of direct fired furnace.

Regenerative pot furnaces are now extensively used with raw producer gas, clean producer gas and natural gas, and have been so improved that greater economy of fuel is obtained as well as largely increased production. These furnaces are built for 14, 16, 18 and 20 pot capacity, the pots being of such dimensions as to contain from 3000 to 4000 pounds of glass; and, where working conditions will permit, the melts are made in about 24 hours after filling.

Early Tank Furnaces

While the continuous melting regenerative gas fired tank furnace was first introduced in England early in the sixties, it was not until 1880 that the first furnace of this type was built in the United States. This was built by the engineers of Sir William Siemens at Poughkeepsie, N. Y., and in 1882 the second furnace

of this kind was erected at La Salle, Ill. While much trouble was experienced in the operation of these furnaces, principally because of lack of skill and training, they were really the pioneers and, while only common green and amber bottle glass was made in them, they demonstrated the adaptability of this type of furnace for various lines of glass manufacture. Information gained from the operation of these tank furnaces enabled William F. Modes and others to design a modified form of Siemens regenerative tank furnace which they afterwards installed at the works of the Streator Bottle & Glass Co., Streator, Ill. and subsequently in a number of other factories for the manufacture of bottles. It was in 1884 and 1885 that the first successful continuous melting tank furnace for the manufacture of window glass was introduced at Streator, Ill. by the Streator Window Glass Company.

Natural Gas and the Glass House Migration

While the furnaces above mentioned were operated with raw producer gas made in the old type of Siemens natural draft producers, it was at this propitious time—1883 to 1885—that natural gas was first utilized as fuel for the manufacture of glass. The first use of natural gas in a glass furnace was in 1883 at the works of the Bradford Window Glass Co. at Bradford, Pa. Its first application was not successful and it was not until 1885 that the furnace was properly arranged to utilize this fuel effectively. The first introduction of this fuel to a flint glass melting furnace was made at the Riverside Glass Works, Wellsburg, W. Va.; and it operated successfully and economically from the beginning. The discovery of this valuable fuel in such abundance, its cheapness and ease of application without serious alterations to the furnaces in use at that time, caused a complete revolution in the glass manufacturing industry; evolution might be a better term to use but those who can remember the rapid changes and enormous increase in the number of factories, their migration from place to place, will agree that it is difficult to find a term that properly expresses the rapid development of this industry, due solely to the abundance and cheapness of natural gas. Its adoption and use by the manufacturers of the Pittsburgh district was attended by what is now understood to have been criminal

carelessness and waste; the pipe lines were carelessly laid in the haste of rival gas companies to be first in the market, and ridiculous inducements were offered manufacturers to use it on a contract basis that was an incentive to waste it, and it was not until some years afterward, when it was sold by meter measurement, that, even with the low price prevailing at the time, was there any encouragement or inducement to economize in its use. After comparatively few years of revelry in the super-abundance of this most ideal natural fuel, the fields in close proximity to the Pittsburgh district began to be exhausted, and then commenced the great migration to other fields. In 1885 the great Karg well was struck in Findlay, Ohio, and the boomers of that town immediately began to offer inducements to glass manufacturers to move their plants, or build new ones in that vicinity. They offered free land for a factory site, natural gas for fuel absolutely free and, in many cases, as a further inducement, a cash bonus to assist in building the factories. Gas in the meantime had been discovered in other localities contiguous to the Findlay district and in comparatively few years a very large glass industry had been built up in that section. The same waste and disregard of economy prevailed here that was practiced in the Pittsburgh district, with the result that the supply was rapidly exhausted, and the manufacturers began to look for other locations.

In the meantime, natural gas had been discovered in Indiana in the neighborhood of Marion, which was afterward developed into a very wide, extensive and prolific field, and the booming of numerous towns was here repeated—free land, free gas and cash bonuses induced the establishment of a large number of factories in districts where hitherto the glass business had been unknown. The experience in this district was similar to that of Findlay, Ohio, and Pittsburgh and resulted in a number of the factories moving to the gas fields of Kansas. Upon the exhaustion of the gas in Kansas district, the industries moved to the gas fields of Oklahoma and Texas, where they are still holding on and operating with the hope that they have at last found an inexhaustible fuel supply. There are factories in this district which were built by parties who originally left the Pittsburgh district and have moved to each succeeding gas field. There are few who realize the extent of this migration or evolution in the glass business.

In the Pittsburgh and Ohio River districts a great many of the old established glass manufacturing companies have actually gone out of business, largely due to the unusual competition of cheap natural gas and methods employed by newly created manufacturing institutions unfamiliar with the glass trade. There are many conservative business men who are of the opinion that the use of natural gas in this industry has not been of permanent benefit to those engaged in the business, although great benefit has resulted in the improvement of the quality of the glass produced as the result of the use of this fuel.

The state of West Virginia appears to be the most prolific field and source of supply at the present time and is serving a very wide district outside of the locality where the wells are located. Pittsburgh today depends very largely upon this district for its fuel. A very large glass industry has been established in this state and the manufacturers have the advantage of being located where there is an abundant supply of bituminous coal, so that the substitution of coal gas producers in this district will obviate the necessity of moving to other localities when the natural gas is exhausted.

From the city of Pittsburgh alone thirty-three glass manufacturing establishments have either moved to other localities or have gone out of business entirely; thirty of these were from the "South Side" alone. In the Findlay, Ohio, district there were at one time over thirty glass factories in operation; today there are none; all having been abandoned or moved to other localities. In the Indiana district, while many of the factories have moved elsewhere, a number of them have adopted the use of gas producers and still maintain their business on a permanent fuel basis by using coal.

Naturally, this great movement of glass factories and the establishment of new ones, together with the improvements in furnaces, the adoption of the continuous melting tank and other innovations furnished the opportunity for the establishment of the business of building glasshouse furnaces and appliances, and it was in 1884 that the writer first engaged in that business.

(*To be continued*)

THE MANUFACTURE AND TREATMENT OF GLASS MELTING POTS*

By W. K. Brownlee and A. F. Gorton[1]

ABSTRACT

Manufacture of glass melting pots.—The raw materials used, the methods of grinding and mixing the raw clay and grog, and the way in which pots are built and dried are *briefly described* for the purpose of impressing glass makers with the amount of labor and care involved. At present only one grade of pot is made; but the difficulty of getting a pot suitable for all kinds of glass suggests the desirability of making special grades of pot for use with specified kinds of glass.

Proper treatment of pots by the glass maker.—The authors emphasize the importance of gently handling pots and of storing them in a warm and dry place. The precautions to be taken in preheating pots in arches are discussed at length for this is the critical period in the life of the pot. The batch should be properly crushed and mixed and should either be preheated or loaded in gradually; and the furnace temperature should be carefully regulated. It is particularly urged that the technical treatment of pots in the glass be entrusted to a man trained in ceramics and physical chemistry.

Arches for heating glass melting pots.—After discussing the usual design the authors *suggest improvements* as to fire box locations, construction of walls and door, etc.

Introduction.—The subject of glasshouse refractories and their treatment in glass plants, despite its obviously fundamental importance in the industry, has received as little attention in the publications of the American Ceramic Society as almost any other topic that could be mentioned. In the 19 volumes of the Transactions, there are two papers dealing with the subject, both of a general nature, and not calculated to afford direct assistance to either the pot manufacturer or the glassmaker. Periodicals devoted to the glass trade are singularly innocent of information on this subject, and perhaps the only publication of recent times devoting a fair amount of attention to pots and their usage is the (British) Journal of the Society of Glass Technol-

* Read at meeting of the Northern Ohio Section of the Society, June 7, 1920.

ogy. This state of affairs is to be deplored all the more because there was never a time in history when the need of sincere coöperation, mutual criticism and common counsel of the pot manufacturer and the glass maker was more urgent than at the present day. Many conditions that have developed since 1915, which are traceable to the War and our participation therein—such as the disappearance of German clay, the search for a substitute among American bond clays, the demand for greater production which caused our glass manufacturers to speed up, incidentally forcing pots both in the arch and in the furnace, and maintaining higher furnace temperatures; and, finally, the production of heat-resisting glasses of the Pyrex type, boiler gauge tubing, "high-pressure" glass, etc., all of which require not only higher temperatures (close to 2800 degrees Fahr.) but also longer melting period—all of these conditions certainly make apparent the need of research and the publication of the results of such investigation in a way calculated to reach all manufacturers in the industry.

Though the writers' purpose is to emphasize the need of care in the treatment of pots after they leave the pot factory, methods used in their manufacture will be briefly touched upon, with the idea of convincing the glassmaker that an article on which so much tender care is lavished in its early stages is deserving of the very utmost in the way of intelligent treatment in its period of usefulness. Certainly the manager of a glass factory labors under a very serious handicap if he is not thoroughly acquainted with the possibilities and peculiarities of the clays entering into the makeup of the pot, for the success of his enterprise depends as much on the average length of life of his pots as on his ability to produce good glass. When a pot fails prematurely (say, before the third melt), if all elements of cost are taken into consideration, such as the cost of pot and contents, of fuel and labor, and the consequent loss of production before another pot can replace the damaged one, the total may represent a loss of $800.00; hence it is clear that the glass manufacturer will profit greatly by using every possible precaution calculated to prolong the life of the pot.

Raw Materials.—The raw clays and burnt material entering into the pot batch should be selected with care, so that the finished pot may possess certain definite physical properties, such as (1) low drying shrinkage, permitting of safe drying; (2) good dry strength (tensile or transverse strength), permitting of safe shipment to the glass plant; (3) low burning shrinkage; (4) a structure open enough to withstand the changes of temperature incident to filling and melting operations; yet sufficiently dense to guard against corrosion; (5) ability to withstand high temperatures under load. The old German clay, as Bleininger has recently pointed out, was valuable not alone for its exceptional drying behavior and its open-burning nature, but also because of its low burning shrinkage in the region 2000 degrees—2500 degrees Fahr., which corresponds to the interval between the highest temperature reached in the arch and working furnace temperature. In seeking a suitable American bond clay, it has been common experience that it is easy to procure a plastic, tough clay, but the drying and burning shrinkage is invariably high, so that it has been necessary to mix with such a clay a proportion of sandy, open-burning clay, of low shrinkage. The result, of course, is not equivalent in all respects to the German clay, but undoubtedly is superior in certain respects such as refractoriness; and in actual service such mixtures have yielded creditable results.

Raw clays should be as free from iron and sulphur as possible, and low in carbonaceous matter. As regards the burnt material, "potshell" is still in common use, and a certain amount of calcined clay is added. There are various objections to the use of "potshell," which at best is very variable stuff, owing to the fact that different parts of the pot are subjected to widely different temperatures and therefore reach different conditions of porosity. Potshell should be thoroughly dried, and might with advantage be "rattled," to remove accumulated dirt. Great care is necessary in rejecting black, overfired portions. It is hard to get men nowadays to pick potshell, and the cost of the cleaned material is mounting rapidly, so that it may not be long before pot manufacturers abandon this practice.

Grinding.—The grinding of the burnt stock or grog is an important operation; and the mills should be of a type that will produce the proper amount of fines, so that the raw or bond clay acts as a binder on the largest and smallest particles alike, rather than becoming a filler of voids in which there are no fine particles of burnt clay. Transverse strength tests made on dried bars readily show the influence of the proportion of fines on the strength, and this as well as other points are well discussed in papers by Kirkpatrick and Fulton and Montgomery.[2] It is also known that the proper percentage of fines used to obtain good tensile strength gives to the clay mass the quality of resistance necessary to best withstand corrosion. The pot manufacturer must ever be mindful of the glassmaker's practice, which in a way must govern the degree of density that will enable the pot to undergo the user's treatment. The denser the structure of the pot, the greater is the necessity of more careful temperature control in pot arch and melting furnace. We can build a pot that will permit of rapid heating in the arch, such as arching in four days, and such a composition would not be quickly affected by the filling of cold batch, but the resistance to corrosion is lessened proportionately to loss of density. Hence we must strike a happy medium wherein both requirements are satisfied.

Mixing.—When the required amounts of previously ground raw clay and grog have been weighed, they are carefully mixed together. This is best done in a mixer whose blades are fixed to a horizontal shaft. A concrete mixer or other rotating device will not do the work because, as is known, the rolling motion causes a separation of the coarse from the fine particles. From the mixer the material is elevated and distributed to an open top pug mill, where sufficient water is added to make the whole fairly soft. It is important that little or no water be added after this first pugging, for if the batch is too stiff it will not age properly, and when much extra water is added in the final pugging it does not soak into the mass. The ageing period depends on the nature of the clay—some clays develop maximum strength and plasticity after three weeks' storing, others require months, and in certain cases there seems to be a decrease in strength after the first few

weeks.[3] From the storage bins the clay is conveyed on an endless belt to a wet pan, where a final tempering is given before putting it through a roll machine which cuts it into rolls or clots of a convenient size for the potmaker to handle.

Building.—Little need be said of the operations required in building the pot, since this subject has been adequately discussed elsewhere.[4] Suffice it to say that the pot is built up in layers, the time interval between applications being long enough to permit each layer to stiffen sufficiently to support the weight of the next. Extreme care and skill are used in joining the clay together; and it is of the utmost importance to have adjacent portions of the same degree of softness, otherwise mutual contraction will result in a crack, or at least set up strains which will bring about a leak later on. It is necessary to cover the upper surface of the clay with damp cloth each night as otherwise the natural drying will form a crust on the top.

Drying.—The drying period has always been long in this country—a matter of four to six months or even a year—and the English practice seems to have been in agreement with this. However, modern demands on production are such that the old, slow method is fast being crowded out, and modern science has developed in the so-called "humidity drying" a means of shortening this stage of the pot's life. Already pots have been dried safely in thirty days, even without artificial circulation of the air, and this record may be exceeded in the future.

Modern drying practice demands a careful regulation of the humidity, temperature and circulation of the air of the pot room, and to secure absolute control of these elements, automatic regulating devices are imperative, also recording devices making a permanent record on a chart. If left to itself, the air of a pot room adjusts itself to changes in the state of the clay, that is, at the start, when the room is full of wet clay, the humidity is high (80 per cent or more), and the temperature is greatest at the ceiling whereas the moisture is greatest near the floor. As the pots dry out, the humidity naturally decreases till at the end it reaches 40 per cent more or less, depending on the season of the year. In some plants it is customary to cover the pots completely

with burlap sacks till they are out of danger. How drying proceeds under these conditions is a mystery to many people; but the principle is simple and was first demonstrated by Washburn,[5] the water vapor being attracted downward to regions of greater humidity, thus preventing saturation of the air adjacent to the clay.

Much remains to be done in discovering the possibilities of humidity drying—much information ought to be gained by logical, carefully controlled experiments, and it is a pity that in some cases this has been subordinated to a policy, on the part of the manufacturer of drying equipment, of guaranteeing to dry the article in an exceedingly short time, when as a matter of fact he has no evidence to back up such a claim. It has been shown that valuable results are obtained by distributing the heating pipes evenly over the floor, for this does away with overhead coils and even coils under the windows, effecting great economy, and it also produces even conditions as to temperature and humidity from floor to ceiling. Where temperatures under 80 degrees Fahr. are employed, pots can be dried safely in five weeks after completion by maintaining a minimum relative humidity of 65 per cent, and certain evidence shows that better pots are produced by preserving a *constant* humidity of 65–70 per cent from start to finish.

Shipping.—Pots must be packed carefully in the freight car, as they travel sometimes 1000 miles to their destination, and switching engines are no longer respecters of the sign "glass melting pots"—"switch and couple carefully." It is best to make a crate around each pot, with sufficient padding of hay under the bottom and around the walls to permit a slight give and take. Cleats nailed to the floor, used to prevent horizontal shifting, sometimes cause shearing of the pot bottom, when the train is jolted excessively.

Pot Storage.—Upon arrival at the glass factory, the pots are removed from the car and carried to the store-room. Gentle treatment is necessary on all occasions when pots are moved, as the concrete and brick pavements or floors over which they must travel are usually far from smooth, and carriages of the

springless type are invariably employed. It is well to point out that the bearing surface of the pot carriage or fork must be ample to preclude the danger of straining the pot. On a few occasions the writers have seen a pot fail due to longitudinal cracks in the bottom[6], which developed where the pot was supported by the fork used in moving the pot from the arch to the furnace.

The space devoted to storage should at all times be warm and dry, and must afford complete protection from the weather. It is unfortunate that some glasshouse managers have little regard for the welfare of their pots and apparently do not think it worth while to provide a special store-room, but set them here and there in stray nooks and corners not already occupied by packing cases, barrels or other impedimenta of the basement. Under such circumstances the pots may suffer from chance leaks in overhead piping, or at any rate take up a certain amount of moisture from the air. The place best adapted for storage is undoubtedly the space near the substructure of the furnace or basement, as this is at all times warm and dry. The benefits to be derived from proper care at this stage are more evident when one considers that there are many occasions when it is not practical to cool a pot arch below 110 or 120 degrees Fahr. (this is especially true of "twin" arches, or those with a common wall), hence it is clear that the pot is better able to withstand such rapid initial heating if it has been previously held in a dry place at about 85 or 90 degrees Fahr.

Pre-heating of Pots in the Arch.—We come now to the most critical stage in the life of the pot, the period which largely determines whether the pot is to fall ingloriously after a few melts, or linger on and on for perhaps 60 melts. The heating of the pot in the arch is indeed a delicate subject, and the writers approach it with great trepidation. In what follows it is not intended to bring accusations against the whole glass industry, but simply to point out conditions that can and should be remedied in many plants. The writers' view is no more than an expression of what eminent men in ceramics and in the glass industry have come to believe, and indeed what some glass plants have already put into practice. Whatever was true of the past, the future will un-

doubtedly bring a new era in glassmaking, characterized by an appreciation of the physics and physical chemistry as well as the chemistry of glass melting, a realization of the value of hiring physical chemists and ceramists to supplement the chemist, of placing furnace regulation and pot arch firing in the hands of trained men rather than of the manager, and of buying high-grade recording pyrometers which afford a permanent record of the utmost value.

Pot Arch Design.—The usual arch is exceedingly crude in design, and its defects are so apparent that it is unnecessary to dwell on them at length. The firebox is at the rear, and the flame, whether from coal, gas or oil fuel, rises and curves over a bridge wall, spreads through the arch proper and passes out through an opening in the floor under the pot, or through flues in the side walls. The back of the pot is nearest the bridge wall and is the hottest portion of the pot, while the hood is nearest the door and is consequently the coolest part. Actual tests with thermocouples have shown a difference in temperature of 200–300 degrees Fahr., even at low temperatures between a point over the back of the pot and a point near the bottom of the door. Furthermore it is impossible to carry the heating beyond 2000 or 2100 degrees Fahr., especially where natural gas or coal is used. With oil, the firebox would melt down if the bottom of the pot were raised to 2500 degrees, because of the enormous difference (500 to 600 degrees) between the temperature of arch and firebox. There is great loss of heat through the walls and crown, which are never insulated, and most of all up the stack. Cold air is sucked in through cracks in the door, as may be demonstrated by holding one's hand near the peephole, and the door itself is a good conductor of heat, as is proved by the fact that points inside are lower in temperature than elsewhere in the arch.

To improve these conditions, several courses might be suggested. Walls and crown should be covered with an efficient insulator such as cork brick or silocel, and the door should be in one solid piece, sliding vertically or horizontally and should be heavily insulated. As to firebox location it would be better to have a firebox on each side and do away with the rear firebox, as

this would prevent the direct impingement of the flame upon the back of the pot. Twin arches should be done away with and each should be separate and have its own stack. Needless to mention, each arch should be equipped with couples, connecting with a pyrometer, and some study given to the printed record of every heat.

It is high time that we got away from the ancient idea that any old oven will do for a pot arch. Proper design of the arch is an important point in glass production, and has a decided bearing on the operating efficiency of the furnace, for if a pot is damaged in the preliminary heating, it surely will not last long in the furnace, and when replacements become frequent there is, in addition to the expense of the pot and the labor of setting, a decrease in production due to time lost, and also a falling off in quality of the finished ware. Although the pot in the dried state represents a single piece of clay, as nearly homogeneous as skilled workmen can make it, it is, on account of its fineness of grain, very sensitive to sudden heating and cooling, or to uneven distribution of heat. In this respect "flux grade" tank blocks are in the same class with pots, since both materials must possess a finer grain than "refractory grade" blocks in order to reach the required density at working furnace temperatures.

Heating Schedules.—The average glass manufacturer has hitherto been somewhat careless in his treatment of pots in the arch. Without thermocouples or other instrument to guide him, the furnaceman was expected to bring the pot up gradually to a bright red heat, and the trained eye of the foreman was relied upon in the end to decide when the pot was just right for setting. Where conditions were apparently most favorable, *i. e.*, where natural gas was the fuel used, a common expedient (and, really the only one possible under the circumstances) was to "crack" the valve a trifle at intervals of about 12 hours at the start, and more frequently later on. By actual test, the writers discovered that in one case the temperature jumped upward at a rate of at least 100 degrees Fahr. per hour immediately after the valve was opened, then settled down towards a constant value which persisted for about 10 hours, when the valve was "cracked" again

and the same performance repeated. After reaching a visible red heat the pot was sometimes held at this temperature for days, if it was not needed to replace a broken pot; otherwise it was heated rapidly in order to set it at an early moment. In other plants coal was used as fuel in the arches, and most of us need not be told how difficult it is to maintain a gradually rising temperature with solid fuel.

Now, happily, conditions are changing rapidly for the better, and the writers sincerely trust that in the future such practices as described above will be considered "beyond the pale." Progressive manufacturers are installing thermocouples in their pot arches, with an indicator for the furnaceman and a recorder in the manager's office, and are studying the charts of successive heats, with an honest effort to determine the type of time—temperature curve best suited to their particular conditions. The senior writer, having had years of experience in actual operation of glass furnaces, may be pardoned for suggesting a heating schedule which in his opinion represents a safe guide in this most difficult operation. The schedule follows:

Interval Deg. F.	Rate Deg. per hr.	Time Hrs.
80– 400	8	40
400– 900	12	41
900–1500	10	60
1500–2200	20	35
	Total time,	7+ days

While pots have often been heated in 3 days or less, with apparently good results, evidence based on pot reports covering a period of several years shows beyond a doubt that best results are obtained by taking seven days or more for preheating. Now it is well known that glasshouses have "streaks" of bad luck, or periods during which the pots leak after a few melts, or even after glazing. Though there are probably other contributing factors, the writers wish to put forward two explanations of this phenomenon: (1) when pots fail prematurely, the demand on the arches is increased, and the preheating is therefore accelerated in order to meet the demand, (2) limited arch capacity prevents time being taken to cool the arch to 80 degrees Fahr., hence the initial strain

of heating is intensified. Pot records show that in these periods of bad luck the breakage is not confined to pots made by any one potmaker, but all suffer alike; and it is difficult to explain the wide variety of service given by pots made in the same room, or in the same set, if the blame be laid solely on the potmaker, or on chance variation in the clay.

Need of Reaching Higher Temperatures in the Arch.—It will be noted that in the above schedule the last stage extends from 1500 to 2200 degrees Fahr. While it is a fact that it is impossible at present to attain higher temperatures, due to faulty construction of the arch, and, indeed, many pots are set at a temperature below rather than above 2200 degrees Fahr., we nevertheless maintain that an increase of 200 or 300 degrees would greatly lengthen the average life of pots, by producing in the preheating stage those changes in shrinkage and porosity which are ordinarily left to the furnace itself to bring about. Now it is a fact that American bond clays, especially ball clays, experience a serious alteration in volume and porosity in the temperature interval cone 1 to cone 12, which corresponds approximately to the range between the highest temperature of the arch and melting furnace temperature; hence it is clear that in order to produce these changes gradually it will be necessary to reach the latter temperature (*i. e.*, 2400 degrees or more) in the arch itself.

One of the writers once had an experience with a pot which was heated very carefully in the arch, 7 to 8 days being consumed in the operation, but the final temperature before setting was 1960 degrees Fahr., and this pot after 12 melts (30 days) failed from a crack in the bottom This is not surprising when one considers the great contraction induced in the clay by suddenly plunging it into a furnace at 2300–2350 degrees Fahr.

The English practice of leaving a pot empty in the furnace for 3 days in the hope of thoroughly burning the bottom will not appeal to the American glass manufacturer, for obvious reasons, and we do not see how such an expedient could obviate the danger mentioned above. Evidence from reliable sources shows that in nearly every case where pots are heated up in the furnace, not

in the arch—as is true of new furnaces or newly repaired furnaces —the life of the pots is doubled. This is presumed to be due to continuity of heat treatment together with a slow rate of heating. Bleininger[7] has shown that pots of the porcelain type require heating above 2500 degrees in order to be serviceable, and in commercial usage it is known that such pots are carried to a very elevated temperature in the arch by means of oil-burners.

Pre-heating the Glass Batch.—The vertical cracks which often appear on the inner surface of the walls of a pot, near the melting line, are usually referred to as "batch cracks," the idea being that they are caused by the strains set up in filling and melting the glass batch. Certainly it must be a great shock to the pot to receive a load of 3000 pounds of cold (and sometimes damp) batch, especially when this quantity is shoveled in at one operation, and the room inside is so limited that when melting begins a stream of glass forces out the stopper and the plug in the proof-hole. The question has been raised whether the glass manufacturer might not with profit preheat his glass batch to, say 700 degrees Fahr., thereby lessening this great initial strain on the pot. This might be accomplished with specially constructed batch wagons equipped with screw conveyors, or by some other mechanical device. The reason for supposing that this would to some degree be beneficial lies in the fact that pots which are kept filled with ladled glass (reference is to the "working pots" used with automatic bulb-blowing machines), and are therefore maintained steadily at a constant temperature, often last anywhere from a year to two years or more.

Need of Care in Crushing Batch Materials and in Mixing the Batch.—Most glasshouses in recent years have installed jaw crushers or similar devices for reducing their cullet, and a few are up-to-date in the matter of mixing machinery, but it has not been a great while since such matters were passed over as unworthy of serious attention. In spite of all precautions it is still possible to go into the most modern glass plants and pick large chunks of cullet out of the batch wagons. Though the alkalis are usually in a finely-divided state, the writers know of at least one large plant where it was quite common to see the soda ash in lumps. It is

not the writers' intention to dwell on the importance of thoroughly pulverizing and intimately blending the batch constituents, as everyone nowadays realizes that both the time of melting and the temperature required directly on the degree of contact of the materials. When these matters are neglected, not only is it more difficult to produce first-quality ware, but in addition the length of life of the pots is greatly reduced by corrosion. When one inspects pots which have been recently removed from the furnace, it is noticed that where there is evidence of corrosion, it is always more marked towards the back of the pot. Since the heat is most intense at the back, melting starts in that region first, hence if the alkalis are not thoroughly assimilated they will attack the pot wall and flux the clay. Occasionally there is evidence of marked corrosion of the crown. It has been customary to assume that this is caused by volatile impurities in the potash or soda (*i. e.*, alkali chlorides or sulfates) which sublime and attack the clay in much the same way that a salt glaze is produced on sewer pipe. It was also inferred that this fluxed clay might drip down into the glass and cause stones. A recent example of this action, which looked like a honeycombed crust on the inner surface of the crown, was submitted to a chemical analysis, with the result that no chlorides or sulfates were found, but merely aluminium silicate with small amounts of potash and iron oxide. In the absence of volatile elements, it is possible that this action was due to the fluxing of the crown by lumps of alkali lying on top after the batch was shoveled into the pot. As previously explained, pots are filled often so completely with batch that it forces out the stopper when melting begins.

Relation of Furnace Temperature to Pot Failure.—Glass manufacturers often remark, in criticism of present-day pots, that in the old days when German clay was in use, there was little trouble due to pots bulging in the side. It is true that pots often fail by bulging or "squatting" in the furnace, but the real explanation is quite apart from the presence or absence of German clay. Anyone who has a slight knowledge of modern ceramics will ridicule the suggestion that a relatively fusible clay like the Grossalmerode[8] could possibly heighten the

refractoriness of an American pot batch. The true cause lies in certain conditions attributable to the war and its natural after-effects. In the writers' opinion there are three factors at work: (1) replacement of German potash and possibly other constituents of the batch by materials which make melting more difficult (*i. e.*, increase the melting period or temperature); (2) the great demand for glassware which necessitates working many plants on 24-hour schedules, and the consequent tendency to shorten the time required for melting operations so as to increase production; (3) the present tendency towards glasses difficult to work such as "Pyrex," that is, glasses melted at temperatures near 3000 degrees with a minimum of fluxes. All of these factors, or certainly the last two, should be blamed for the softening or bulging of pots in the furnace.

Manufacturers of heat-resisting glasses realize that it is not practical to melt such glass on a commercial scale in pots, and have therefore, as far as possible, resorted to tanks. Very small tanks ("day" tanks) are being used successfully, as they can easily be maintained at 2800 degrees or more during the melting period and the glass is quickly worked out, while there is no softening of the walls as is the case with pots. However, corrosion is evident at the flux line at an early stage, and it is probable that it is going to be a difficult matter to find fire-clay blocks which will stand up under such service. Pots which have given two melts of "high-pressure" (gauge-tubing) glass often bulge out in the sides so that the clay cracks open and the inner surface of the bottom resembles a plowed field. As regards tanks, it might be well to point out that no commercial "flux" blocks are ever burned at a higher temperature than that corresponding to cone 12, hence it is quite evident that blocks intended for use against heat-resisting glass will have to be burned to a much higher temperature in the kiln, if rapid corrosion is to be avoided. The other alternative is to seek a material much more refractory in nature than fire-clay, and this course will probably be more productive of results in the end.

What may be regarded as an indirect result of the present demands for heat-resisting glass is the idea which has already been advanced by pot manufacturers and glass manufacturers of

differentiating pots according to the use to which they will be put, and of making and selling a certain grade of pot for use with specified kinds of glass. This will be of immense benefit, for hitherto pots have been sold regardless of the character of glass to be made in them, and therefore it has been necessary for pots to give good service under varying conditions. For instance, it is known that lead glass causes marked corrosion of the bottom of the pot, whereas lime glass confines its damage more to the ring and the walls near the melting line. Density of the glass figures prominently in this action, as was shown very cleverly by Rosenhain.[9] Moreover, it has been customary in the past to use burnt flint clay in pots intended for lime glass, but this could not be used in lead glass pots because of the danger of throwing stones. It is to be hoped that this idea of classifying pots and of selling a pot for use with a particular kind of glass will merit the attention from the industry that it deserves.

Conclusion.—In concluding these remarks, the writers wish to emphasize the point that the technical treatment of pots in the glass plant should be entrusted to specially trained men. The furnaceman for obvious reasons should not have this responsibility, and the foreman and the manager, while they have a deeper appreciation of technical matters, are very busy with other questions pertaining to production. Neither should the burden be placed on the chemist, who has all he can do to see to the purity of raw materials and to adjust the glass for color, etc. This duty may safely be entrusted to a young man who has been adequately trained in ceramics and physical chemistry. When more glass manufacturers see the justice of this statement, and employ such men in their plants, real teamwork between the pot factory and the glass factory will be possible, and certain troubles which have afflicted the industry for years will to a great extent disappear.

THE BUCKEYE CLAY POT CO.
TOLEDO, OHIO

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NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

THE "WHY" OF AGEING CLAY[1]

By H. Spurrier

ABSTRACT

Ageing of clay.—(1) *Evolution of* CO_2 was found to continue for over 34 days after pugging and, like the change of plasticity, to proceed more rapidly between 80° and 90° F than below 60°. (2) *Effect of replacing water by non-aqueous liquids* was to inhibit the development of plasticity altogether. (3) *Effect of a dilute solution of* H_2O_2 was to produce a pronounced increase of viscosity and also to stimulate the growth of filaments algae and the consequent evolution of both CO and CO_2. It seems probable, therefore, that the change of plasticity of clays with time is due, in some way, to the growth of such algae. (4) *This algae theory* would explain all the effects found.

New chemical measure of the plasticity of clays.—The ratio of the amounts of Al_2O_3 and SiO_2 dissolved by caustic potash was found, for the three clays tested (Cooley Ball, Edgar Plastic Kaolin and Harris Spruce Pine), to decrease rapidly with diminishing plasticity and therefore might well be used as a quantitative measure of plasticity.

In 1918 a method[2] was developed for the determination of air in pugged clays, by means of which the occluded gases were liberated in a form which made further handling a very easy matter. It seemed desirable to determine the composition of such gases and while it was anticipated that some deviation from a true air composition might occur, it was hardly foreseen that both carbon dioxide and carbon monoxide would be found.

The following composition was, however, found for gases recovered from clay that had been pugged but twenty-four hours previously:

	Per cent
Carbon dioxide	3.85
Oxygen	13.46
Carbon monoxide	1.92
Nitrogen	80.77
Total	100.00

[1] Received Nov. 12, 1920.

[2] Spurrier, This Journal, 1, 710 (1918).

In the note announcing this composition it was remarked: "It is obvious of course that these chemical changes are intimately connected with the well-known physical changes that take place during the ageing and weathering of clays. Some light might in this way be thrown upon the much studied and as yet imperfectly understood question of plasticity." Experiments designed to throw further light on this phenomenon were undertaken, and while in no way complete, some facts have been developed which seem of sufficient interest and possible utility to warrant publication.

In the ageing of clay bodies it was found that plasticity increases at temperatures of 80°–90°F faster than at a temperature of 60°F. Since it was known that the oxygen occluded as air in clays was speedily converted to carbon dioxide and carbon monoxide, it became interesting to know positively whether clay bodies gave off carbon dioxide under ageing conditions. Accordingly a five-pint bottle was cut off close to the bottom and the edge ground smooth. The bottle was inverted and through the two-hole stopper were passed the two ends of a small glass coil in such a manner that the coil was in the shoulder of the bottle. Enough water to immerse the coil was placed in the bottle. A Chromel gauge screen was fitted above the water and upon this were placed the freshly pugged clay blanks and above this was placed a small beaker containing barium hydroxide solution. A glass cover completed the set up.

Almost immediately the barium hydriate showed the presence of carbon dioxide. Each morning the vessel was blown out with fresh air and the barium hydrate solution was renewed. This was continued for 34 days and even on the 34th day carbon dioxide was still coming off in such quantity that a thick scum formed promptly on the surface of the liquid. During this experiment, it was noted that carbon dioxide was evolved more rapidly between 80° and 90°F than when the water circulating in the coil was kept below 60°F. As previously noted, plasticity increases most rapidly between these temperatures. The conditions of the experiment insured a saturated atmosphere during the whole period.

As is well known, there is a close relation between the plasticity

of a clay and the viscosity of slip made therefrom; for instance, if two slips be made from the same clay the one flocculated and the other deflocculated, the viscosity of the flocculated slip will be the greater. In this way relative plasticity may be established in terms of viscosity. Testing in this way, the clay used in the above experiment was found to have much greater plasticity at the end than at the beginning of the experiment.

Following out another line of inquiry, Edgar Plastic Kaolin in separate portions was mixed in a mortar with carbon disulfide, benzene, carbon tetrachloride, ethyl alcohol, ether, bromoform, and sulphuric acid. In no case was the slightest plasticity developed. The mixtures in all cases were granular. Even in the case of sulphuric acid no plasticity was developed until a considerable quantity of water had been added, which was done in very small increments, the mixture being carefully mixed and examined after each addition. From the above the opinion was arrived at that hydroxide ion must be present in order to develop plasticity.

In order to throw some further light on this question, it was decided to try the effect, on a slip, of the addition of 3 per cent hydrogen peroxide. Accordingly two 100 cc Nessler tubes were charged with 100 cc each of a carefully mixed slip. To one, 5 cc of 3 per cent hydrogen peroxide were added and the covered tubes set aside for twenty-four hours. At the end of this time, there was a pronounced increase in viscosity of the slip to which the hydrogen peroxide had been added and no change in the other, as shown by the viscosimeter. The two slips were kept in order to see if any further change would take place. In about a week tiny green specks were noted in the tube that had received the addition of hydrogen peroxide, but very careful inspection with a X-10 lens failed to reveal any such specks in the untreated tube.

One of these specks was removed, examined microscopically and found to be a green alga. On keeping, the tube failed to show much increase in algae and it was thought that, owing to exhaustion of the dissolved oxygen further growth had been arrested. Accordingly, a further addition of 5 cc of hydrogen peroxide was made—with the gratifying result of an almost imme-

diate growth. As the growth seemed to slow down, further additions of hydrogen peroxide were made with consistent increase of filamentous algae. During this growth, the slip became much more viscous, so much so that the volume had to be increased beyond the original 100 cc.

Another change of much interest occurred, namely, the evolution of considerable quantities of gas, which it seemed obvious was the result of vegetal respiration. On closing the tube with a rubber stopper provided with an educt tube, it became possible to collect enough of the gas to test for carbon monoxide and carbon dioxide, both tests resulting positively. Under the circumstances, the presence of the two oxides of carbon might have been confidently postulated, as it is well known that both these gases result from algal metabolism. Mr. Seth Langdon[1] showed that carbon monoxide was produced by the giant Kelps of the Pacific Coast "Nereocystis luelkeana" as a product of respiration, that it is produced in light or dark and only on the surface or floater portion, and that the presence of oxygen is essential to its production. These findings agree well with the above, that the exhaustion of the oxygen in the slip, arrested growth and the addition of oxygen in the form of peroxide of hydrogen, stimulated such growth as it is equivalent to exposing it to moist air. As is well known, algae require air and therefore usually occur upon moist surfaces, but can not thrive when entirely submerged in liquid on account of lack of oxygen.

The cause of the improvement in the plasticity of clay piles that are exposed to damp weather and frequently turned over to expose fresh surfaces, now becomes evident—it promotes algal growth which in some way increases plasticity. There are probably several contributory causes which singly or together produce the complex phenomenon which we term "plasticity" and it might be quite correct to assume that there is more than one kind of plasticity. While some light has been thrown upon this interesting question, one is naturally led to inquire just why algal growth increases the plasticity of clays. This question can only be answered by further investigation which it is intended to pursue as opportunity offers.

[1] Langdon, *Science*, **49**, 573 (1919).

One somewhat confusing point in the effect of algal growth is the copious formation of carbon dioxide, because the writer has observed that the introduction of free carbon dioxide reduces the plasticity of clays. The question of plasticity of clays was concurrently attacked from another angle which yielded data of profound significance.

It became interesting to investigate the action of an electrolyte upon clays exhibiting wide differences in initial plasticity. The treatment was as follows: A quantity of the clay was weighed out which represented 50 grams of dry clay. The necessary weight was calculated from a moisture determination on a separate portion, as it was prejudicial to dry the portion to be experimented on. The weighed portion was made into a slip with 250 cc of water and 83 cc of a solution of 30 grams of caustic potash in 250 cc of water were added. The warm mixture was stirred thoroughly, 500 cc more water were added, and the mixture was thoroughly stirred and allowed to settle. From the clear supernatant liquid, a portion was drawn off, acidified with hydrochloric acid, and the silica and alumina determined in this with great care. The results are expressed as a ratio of silica to alumina, silica being taken as unity in all cases.

The three clays selected were, in the order of decreasing plasticity, Cooley Ball, Edgar Plastic Kaolin, and Harris Spruce pine. It will be noted that the ratio of alumina to silica dissolved by the potash decreases as the plasticity diminishes.

	Dissolved SiO_2	Dissolved Al_2O_3
Cooley Ball	1	2.17
Edgar Kaolin	1	1.009
Harris Spruce Pine	1	0.35

Analyses of the Edgar Kaolin and the Spruce Pine showed the following figures:

	Edgar kaolin	Harris spruce pine
Silica	46.49	46.30
Alumina	38.85	38.57

Theoretical Kaolinite gives Silica, 46.6; Alumina, 39.49; $SiO_2 : Al_2O_3$ as 1 : 0.847.

The residues from the above experiments were washed until free from alkali and examined. The Harris clay residue lacked

all semblance of plasticity and was not sticky. The Edgar Kaolin residue was slightly plastic and more sticky than originally. The Cooley Ball clay residue was somewhat plastic and showed extraordinary stickiness.

It would seem that the determination of the ratio of alkali soluble silica to alkali soluble alumina, throws so much light on the character of a clay as to at once distinguish, by chemical data, differences between clays that ordinary determinations of silica and alumina would entirely fail to indicate.

The practical potter of experience distinguishes readily between sticky and plastic clays by the "feel." The above procedure also does this and the results can fortunately be expressed in figures.

The writer is fully conscious that the above data are hardly sufficient and need the confirmation and elaboration of further experiment, but he expresses the hope that the above will suffice to stimulate others to further activity in this direction.

DETROIT, MICHIGAN

THE USE OF PLASTIC CLAY GROG IN PREVENTING SPALLING[1]

By Raymond M. Howe and Stewart M. Phelps

ABSTRACT

Effect of calcined clay grog on the properties of fire-brick.—A medium dense-burning clay was calcined at cone 8, then ground and mixed with plastic clay in various proportions up to 40 per cent. An air spalling test of the burned bricks showed that the grog increased the *resistance to spalling* about 5 per cent for each per cent of grog added. The results for *other physical properties* agreed with those found by previous observers; the bricks with grog were more porous and weaker mechanically but showed less drying and burning shrinkage.

1. Introduction

When fire-brick become partially vitrified their resistance to temperature change is lessened and sections spall off.[2] Coarse grinding, soft burning, and a uniform open structure favor high resistance to spalling; where two or more clays are available, the use of a large proportion of open burning clay is desirable. In certain localities, however, it is impossible to change the grind, firing procedure, or process of manufacture applied to the single available plastic clay. Consequently it was decided to calcine a portion of raw clay and to introduce the resulting grog as a part of the batch. This method of overcoming spalling is by no means original but at the same time no quantitative data are available which concern the direct application of plastic clay grog in reducing or overcoming spalling.

2. Results of Previous Investigations

Geijsbeck[3] has stated that the drying and burning properties of ceramic bodies could be improved by the addition of grog, and that the quantity of, rather than the size of, the grog is the

[1] Received May 24, 1920.

[2] R. M. Howe, *J. Am. Ceram. Soc.*, **3**, (1920).

[3] S. Geijsbeck, "Note on the Action of Grog in Ceramic Bodies," *Trans. Am. Ceram. Soc.*, **1**, 133 (1905).

controlling factor. The first ten per cent produces the most noticeable change in the properties of the mix.

Rigg[1] concluded that the use of grog was desirable, for its incorporation into the batch results in the general improvement of the finished product. He did not advise the use of coarse or fine grog but advocated using a mixture of fine and medium sized particles.

Fulton and Montgomery[2] found that the water of plasticity, the drying shrinkage, the burning shrinkage and the strength of the green ware decreases with increasing amounts of grog, when from 0 to 75 per cent is used. The strength of the burned pieces decreases, and the porosity increases with the addition of grog until over-burning begins. Fine grog is associated with greater drying and burning shrinkage than coarse grog, and the resulting product is stronger.

Kirkpatrick[3] confirmed Rigg's results and concluded that the strength of fire-clay bodies depended upon the size of the grog; it should not be too coarse or too fine, but should be present in several sizes.

The preceding citations give valuable information but do not apply directly to spalling. Windzus,[4] however, investigated the subject and stated that spalling may be reduced by increasing the size of grog, or by reducing the plastic content of the batch. These conclusions, reasonable though they are, were not warranted by his few simple experiments.

When the preceding statements are summarized, they apparently justify the following conclusions:

When grog is added to plastic fire-clay the resulting mixture is more porous; it possesses superior drying and burning properties, but is weaker before and after burning. The size and quan-

[1] Gilbert Rigg, "The Application of Grog in Fire-brick Manufacture," *Met. Chem. Eng.*, **8**, 523 (1910).

[2] C. E. Fulton and R. J. Montgomery, "Effect of Grog in a Fire-clay Body," *Trans. Am. Ceram. Soc.*, **17**, 409 (1915).

[3] F. A. Kirkpatrick, "Effect of Sizes of Grog in Fire-clay Bodies," *Trans. Am. Ceram. Soc.*, **19**, 268 (1917).

[4] P. Windzus, "Resistance of Refractory Ware to Abrupt Changes in Temperature," *Tonind. Ztg.*, **36**, 1205 (1912); *Met. Chem. Eng.*, **10**, 662 (1912).

tity of the grog control the physical properties of the mixture and of the burned product.

3. Present Investigation

A. Materials.—A medium dense burning plastic clay fusing at cone 30 was taken as the basis of the experiments herein described. A large amount of this clay was calcined at cone 8 and after being crushed to the necessary degree of fineness, it was used as grog.[1] The analysis of the grog is as follows:

Silica	63.86
Alumina	30.13
Ferric oxide	3.79
Calcium oxide	.76
Magnesium oxide	.44
Alkalies	.86
Total	99.84

B. Preparation of Samples.—Commercial sized batches were made which had the following compositions:

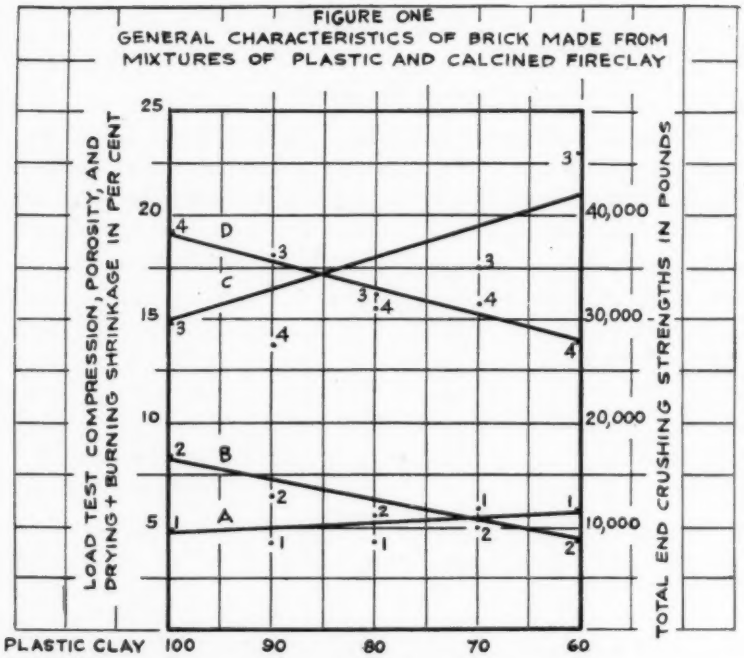
Number	Plastic clay Per cent	Grog Per cent
B- 0	100	0
B-10	90	10
B-20	80	20
B-30	70	30
B-40	60	40

These mixtures were tempered in a pug mill, shaped in an auger machine, dried, and burned to cone 8.

C. Results of Physical Tests.—Representative samples of each of the five mixes were subjected to those tests which indicate the physical properties of fire-brick or which measure their relative resistance to spalling. The standard methods of the American Society for Testing Materials or of the American Ceramic Society were used for those tests which have been standardized. The results of the general tests are plotted in figure 1. The

[1] The term "grog" appears to have several meanings in the different ceramic industries, for it applies to raw flint clay, calcined flint clay, ground bats, ground biscuit ware, etc. Generally, however, the term refers to material of low plasticity and shrinkage and in that sense applies to this case.

FIGURE ONE
GENERAL CHARACTERISTICS OF BRICK MADE FROM MIXTURES OF PLASTIC AND CALCINED FIRECLAY



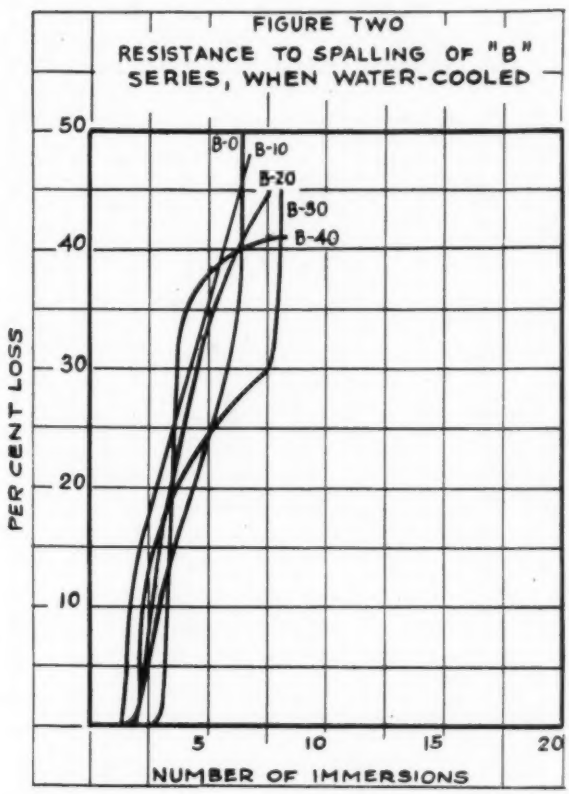
CURVE A (POINTS 1) COMPRESSION IN LOAD TEST
CURVE B (POINTS 2) TOTAL DRYING AND BURNING SHRINKAGE
CURVE C (POINTS 3) POROSITY
CURVE D (POINTS 4) CRUSHING STRENGTH

results of the water spalling tests are given in figure 2, and the air spalling data are presented in figure 3.

4. Discussion of Results

It is evident that the addition of grog to plastic clay results in the formation of a more porous product of the same fusion point when the batch is shaped by the stiff mud process.

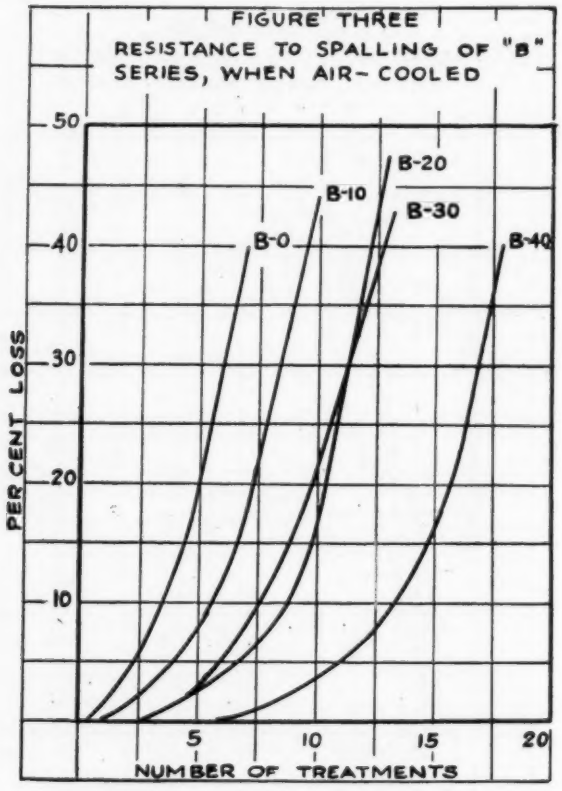
The grogged specimens were weaker mechanically and compressed slightly more in the load test, because of their more open structure. The total drying and burning shrinkage variety inversely with the grog content of the fire-brick, although it is quite probable that the size of the grog is also a controlling factor.



These observations are in accordance with those which have been made by other investigators where laboratory test pieces have been studied.

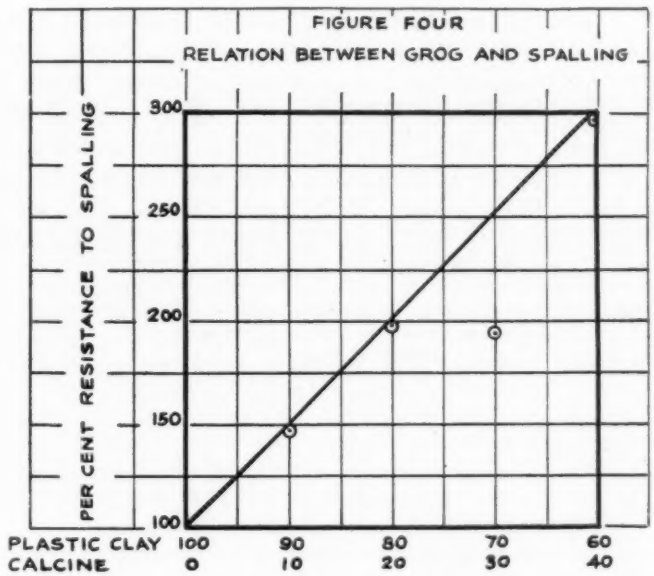
When samples were subjected to the water spalling test it was evident that the treatment was too severe for this type of fire-brick. When the results were plotted there was a slight indication of a difference in structure, although this difference was too slight to permit the drawing of definite conclusions. Consequently samples were air-spalled and results of a more comparable nature obtained. When these latter observations were plotted the effect of grog upon brick structure was shown to be pronounced and very definite conclusions could be deduced.

It is appreciated that the air-cooling test is too slow for certain



types of fire-brick, but it is also evident that the water-cooling test is too rapid for fire-brick of the type under consideration. There are millions of fire-brick made yearly which shatter after a few immersions in water, yet they give satisfactory service in blast furnace linings, stove checkers, soaking pits, and in sidewalls. Figures 2 and 3 show that it is impossible to obtain a distinction between fire-brick of this type with the water spalling test, while a distinction can be obtained by cooling in air. The writers believe that a rough classification can be obtained by means of the water spalling test, but if the specimens fail rapidly more tangible results obtain when they are cooled in air.

Figure 3 shows very clearly the way in which the addition of grog effects the resistance of the product to spalling, but it



was deemed advisable to plot the same data in another manner. Consequently, the abscissae of each curve as its intersection with the 10, 20, 30 and 40 per cent loss axis were averaged. B-0 (the original mixture) was assigned a value of 100 per cent and when the various abscissae were compared it was possible to compute the resistance to spalling of each mixture in terms of B-0.

Batch.	B-0	B-10	B-20	B-30	B-40
Abscissa at 10 per cent loss axis....	3.5	5.5	9.0	7.5	13.3
Abscissa at 20 per cent loss axis....	5.0	8.3	10.3	9.8	15.8
Abscissa at 30 per cent loss axis....	6.0	8.5	11.2	11.2	17.0
Abscissa at 40 per cent loss axis....	7.0	9.5	12.3	12.8	18.0
Average.....	5.4	7.9	10.7	41.3	16.0
Per cent Resistance to Spalling.....	100	147.6	198.7	191.6	295.9

When these calculations were made it became obvious that the addition of one per cent of grog increased the resistance of these mixtures about five per cent with respect to resistance to spalling. The samples B-10, B-20 and B-40 conform to this rule very closely, although B-30 for some unknown reason does not. It appears justifiable to state, however, that the addition of grog

up to 40 per cent, increases the resistance of the brick structure to spalling about five per cent for each per cent of grog added, under the conditions of the investigation. However, this statement does *not* warrant the conclusion that all grogged bodies are more resistant to spalling than all of those free from grog. It should be more closely limited to the statement that *the calcining of a portion of this particular clay increased the resistance of the product to spalling to a remarkable degree.* Such a statement undoubtedly applies to any one particular plastic clay.

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EXPERIMENTS IN DEAD-BURNING DOLOMITE AND MAGNESITE[1]

By H. G. Schurecht

ABSTRACT

Stability of calcined dolomite; effect of fineness of raw material, nature of flux and temperature of burning.—Dolomite is difficult to dead-burn because the absorption of moisture from the air produces a gradual slacking due, probably, to the hydration of lime and various lime compounds, and this tends to cause disintegration. With all the fluxes tried, 100 mesh raw material gave greater resistance to slacking than 8 mesh size. This resistance decreased, however, with increasing temperature of calcining, by an amount which seems to depend on the silica and alumina content of the flux, being greatest for basic open hearth slag and kaolin, less for flue dust, and iron ore, and least for roll scale. The stability also varied with the proportions of flux used, being greater, as a rule, for smaller proportions.

Shrinkage, porosity and vitrification of calcined dolomite; effect of flux and burning temperature.—The shrinkage and porosity curves for mixtures containing flue dust, iron ore or roll scale are very similar. The higher the proportion of flux, the lower the temperature required to get maximum shrinkage and minimum porosity. Kaolin and basic open hearth slag behaved peculiarly in that vitrification depended more on the burning temperature than on the proportion of flux used.

Experiments in making dolomite brick.—It was found that ageing of the wet calcined material was necessary to prevent cracking of the bricks upon drying. With 5 per cent $MgCl_2$ as binder, comparatively strong brick were obtained. High shrinkage on firing caused excessive cracking, but the bricks were extremely dense and did not disintegrate until after four to six months. Unfired tar-bonded brick were made with sufficient strength to stand shipping and with a storage life of about four months. Fired tar-bonded brick showed less shrinkage and cracking than similar brick made with water. If dipped in tar to protect them from moisture, such brick will last five or six months before disintegration. It is possible, then to make dolomite brick with a storage life long enough to allow shipping and placing in furnaces.

Stability, shrinkage and porosity of calcined magnesite; effect of flux and temperature of burning.—Unlike dolomite, magnesite showed less slacking effect the higher the temperature of burning. Roll scale gave greater stability than iron ore, probably because of its lower silica content. The product was comparatively porous and with low shrinkage, even with high proportions of roll scale.

[1] By permission of the Director, U. S. Burean of Mines

Introduction

In 1913, 158,519 tons of calcined magnesite[1] were imported into the United States from Austria Hungary. During the war this supply was cut off and American manufacturers were forced to rely chiefly upon California, Washington and Canadian magnesites. Chiefly as a result of this condition production of crude Californi magnesite increased from 9,632 tons in 1913 to 211,663 tons in 1917, while the importation of Canadian magnesite increased from 494 tons in 1913 to 20,872 tons in 1918.

Canadian magnesite was used largely because of the remoteness of the Californi and Washington deposits from the middle east steel centers. Dolomite in abundance occurs near the steel centers and an extremely pure material may be obtained at comparatively low cost.

The untreated domestic magnesite is rather pure and not as satisfactory as the Austrian magnesite, known as Breunnerite, which contains sufficient iron carbonate to render it suitable when calcined for the manufacture of refractories. Sufficient flux should be present in magnesite to prevent the calcined material from slaking and to produce a dense product.

Dolomite is comparatively difficult to dead-burn owing to its tendency to disintegrate. This disintegration may be divided into two classes:

(1) Disintegration due to change of state on heating and cooling.

(2) Disintegration due to slacking by taking up moisture from the air.

In the first case the disintegration is comparatively rapid, occurring during the cooling, and is due to the conversion[2] of the beta to the gamma from of calcium orthosilicate, $2CaO.SiO_2$ which starts at 675°C in cooling and continues even after it is taken out of the furnace. The conversion is accomplished by an increase in volume of 10 per cent, which shatters the calcine into fine dust and sometimes breaks off fragments of the sintered dolomite. This action is called "dusting" and is well known

[1] C. G. Yale, and R. W. Stone, "Magnesite in 1918," *U. S. Geol Survey, Mineral Resources of the U. S.* **1919,** 141–158.

[2] G. A. Rankin, "The Ternary System $CaO–Al_2O_3–SiO_2$," *Am. Jour. Sci.*, **39,** 7–8 (1915).

in the manufacture of Portland cement. Bates[1] found in Portland cements high in magnesia that the amount of orthosilicate formed is decidedly increased.

The writer noticed dusting in the cooling of calcined Canadian magnesite which contains a high per cent of lime. The conversion of the orthosilicate in the heating and cooling of Canadian magnesite has caused considerable trouble in the use of this mineral for making brick as the dusting tends to disintegrate the brick.

Disintegration due to taking up moisture from the air is due to the presence of free lime in the calcine, which readily takes up water and forms $Ca(OH)_2$. In the formation of the hydrate the lime increases in volume and finally disintegrates the mass. Disintegration of this type takes place comparatively slow.

Hydraulic compounds may be formed with lime which take up moisture from the air and cause the sintered dolomite to disintegrate. Some of the possible compounds formed in calcined dolomite are the following:

CaSiO	$3CaO.Al_2O_3$	$CaO.Fe_2O_3$
$3CaO.2SiO_2$	$5CaO.3Al_2O_3$	$Al_2O_3SiO_3$
$2CaO.SiO_2$	$CaO.Al_2O_3$	$CaO.Al_2O_3.2SiO_2$
$3CaO.SiO_2$	$3CaO.5Al_2O_3$	$2CaO.Al_2O_3.SiO_2$
$CaOMgO.SiO_2$	$2CaO.Fe_2O_3$	$3CaO.Al_2O_3.SiO_2$

Klein[2] found that $2CaO.SiO_2$ (B form) and $3CaO.SiO_2$ and all of the aluminates with the exception of the tricalcium aluminate developed hydraulic properties.

Campbell[3] found that calcium ferrites corresponding to the following empirical formulas showed hydraulic properties and when tested as to their ability to set, showed an initial set in 14 to 22 minutes, and a final set in about $^3/_4$ of an hour, being similar to the calcium aluminates found in Portland cement.

1. $5CaO.3Fe_2O_3$
2. $6CaO.3Fe_2O_3$

[1] P. H. Bates, "Properties of Portland Cement Having a High Magnesia Content," *Bureau of Standards Tech. Papers*, **102**, 40 (1918).

[2] A. A. Klein, and A. J. Phillips, "The Hydration of Portland Cement," *Trans. Am. Ceramic Soc.*, **16**, 313–841 (1914).

[3] E. D. Campbell, "Some Mix-Crystals of Calcium Ferrite and Aluminate," *Jour. Ind. Eng. Chem.*, **11**, 116–120 (1919).

Furthermore Bates[1] found that high magnesia cements show a tendency to disintegrate upon storage, which may be another cause of the disintegration of dolomite brick.

By "dead burning" is meant, the sintering of dolomite with a flux at a high temperature in order to place it in such a state that it will not disintegrate after storing for long periods. It should also be calcined high enough to remove most of the firing shrinkage.

In work previously reported[2] the writer conducted experiments in dead-burning dolomite by the addition of coal tar, flue dust, iron ore, basic open hearth slag, shale, kaolin, roll, scale, and chlorides when added to raw dolomite, and calcined to cone 18. Fluxes high in silica produced calcines which disintegrated on cooling due to dusting. Fluxes low in silica, as roll scale, iron ore and flue dust were more effective in dead-burning than the siliceous fluxes, as shale and blast furnace slag. The best mixtures, however, disintegrated at the end of 130 days when in the form of briquettes $1\times1\times1$ in., whereas it is desirable to prepare calcined dolomite that will withstand storage for much longer periods.

The former work was done on coarsely ground dolomite (through 8 mesh) and the trials were calcined at cone 18. By grinding dolomite finer, a more intimate mixture is obtained and by calcining to higher temperatures a more thorough sintering takes place. In the following work the dolomite and fluxes were ground to 40 and 100 mesh size and calcined to cones 14, 20 and 26 to determine if finer grinding and higher calcination temperatures would produce a more stable product.

The effects of different fluxes and calcining temperatures on the shrinkage and porosity of dolomite and magnesite were also studied to determine the amounts of fluxes and calcining temperatures necessary to obtain maximum shrinkage.

Various methods for making brick from calcined dolomite were tried, both with hydrous and anhydrous binders.

Description of Work

The effects of fine grinding and different calcination temperatures were first studied.

[1] P. H. Bates, *Loc. cit.*, p. 32.

[2] *Jour. Am. Ceram. Soc.*, **2**, 291–805 (1919).

The following fluxes were added to dolomite ground to 100 mesh size, and similar mixtures were also made with dolomite ground to 40 mesh size:

(1) Flue dust; (2) iron ore; (3) basic open hearth slag; (4) kaolin; (5) roll scale.

The chemical analyses[1] of the fluxes are as follows:

	1	2	3	4	5
Silica (SiO_2)	9.5	7.9	15.9	43.8	4.2
Titanium oxide (TiO_2)	..	0.3	..	....	....
Aluminum oxide (Al_2O_3)	4.6	5.6	7.6	40.2	5.2
Ferric oxide (Fe_2O_3)	72.1	78.2	20.8	0.8	19.6
Ferrous oxide (FeO)	..	...	..	...	71.3
Manganese oxide (MnO)	..	trace	2.3	...	...
Calcium oxide (CaO)	2.5	none	40.6	none	none
Magnesium oxide (MgO)	1.0	0.6	13.0	0.06	0.20
Potassium oxide (K_2O)	0.6	0.04	none	none	0.20
Sodium oxide (Ng_2O)	0.3	0.3	none	none	none
Sulphur trioxide (SO_3)	0.3	none	none	none	none
Carbon dioxide (CO_2)	1.5	none	none	none	none
Hygroscopic water (at 105°C)	0.6	0.5	0.0	1.5	0.0
Loss on ignition	6.8	6.9	..	13.9	...
	99.6	100.1		100.2	100.9

One inch cubes of the various mixtures were molded and calcined to cones 14, 20 and 26 in a Hoskins carbon resistance furnace. Immediately upon being taken from the furnace they were cooled in a desiccator and weighed. After standing in air at room temperature for different periods they were reweighed in order to determine the increase in weight due to taking up moisture and CO_2. The cubes were weighed at the following intervals: 2, 5, 10, 18, 28, 38, 50, 65, 80, 100, 125, 150, 175, 200, 220, 250, 275, 300 and 325 days. The periods at which the briquettes disintegrated and no longer showed mechanical strength were also noted.

Below are given the chemical analyses of the Cedarville dolomite and Canadian magnesite used in the investigation. The analyses[2]

[1] The chemical analyses were furnished by A. G. Fieldner of the U. S. Bureau of Mines, Pittsburgh, Pa.

[2] Analyses were furnished by A. C. Fieldner of the U. S. Bureau of Mines, Pittsburgh, Pa.

of other Ohio dolomites and of calcined Austrian magnesite are given for comparison.

	1	2	3	4	5	6	7
Silica (SiO_2)	0.4	0.6	0.2	0.0	6.7	2.2	0.7
Aluminum oxide (Al_2O_3)	0.5	0.3	0.3	.01	2.5	.6	2.2
Ferric oxide (Fe_2O_3)	.5	.6	.4	.30	1.1	.8	7.2
Ferrous oxide (FeO)	..	..	..	..	..	..	none
Calcium oxide (CaO)	30.2	29.9	30.3	30.20	28.5	11.1	1.8
Magnesium oxide (MgO)	21.8	21.9	21.9	22.0	18.3	39.0	86.1
Potassium oxide (K_2O)	trace	0.2	none	none	0.4	none	none
Sodium oxide (Na_2O)	trace	.04	none	none	.1	none	none
Sulphur trioxide (SO_3)	none	none	none	.1	.1	none	0.2
Carbon dioxide (CO_2)	46.8	46.5	47.5	46.8	41.6	47.1	1.7
Hygroscopic water at 105° C.	0.1	0.1	0.01	0.0	0.2	0.0	0.3

1. Dolomite from Cedarville, O. 2. Dolomite from Springfield, O. 3. Dolomite from Genoa, O. 4. Dolomite from Woodville, O. 5. Dolomite from Hillsboro, O. 6. Magnesite from Canada. 7. Calcined magnesite from Austria.

To determine the effects of different fluxes and calcining temperatures upon the shrinkage and porosity of the dolomite and magnesite mixtures, briquettes ($1 \times \frac{1}{2} \times 2$ inches) were used. Small briquettes were employed in order to minimize cracking, resulting from excessive firing shrinkage, which occurs to a greater degree in briquettes of large size. Five per cent of dextrine was used as a binder in molding the briquettes and the raw volumes were determined in a small pycnometer volumeter. The briquettes were then fired in an electric furnace to cones 14, 17, 20, 23, 26 and 30. After firing the volumes were again determined to obtain the firing shrinkage. The apparent porosities were determined in the customary manner, using kerosene as the liquid. The true specific gravity determinations were made in a pycnometer specific gravity bottle with kerosene as the liquid.

In the experiments in making dolomite brick, the following mixtures, screened through a 100 mesh sieve, were calcined at cone 20, Cedarville dolomite being used.

1. 10 per cent iron oxide, 90 per cent dolomite
2. 15 per cent iron oxide, 85 per cent dolomite
3. 25 per cent iron oxide, 75 per cent dolomite

The following binders were tried:

1. 5 per cent sodium silicate
2. 5 per cent caustic lime
3. 5 per cent magnesium chloride
4. 12 per cent coal tar

Effects of Degree of Fineness of Raw Dolomite and Different Fluxes and Calcination Temperatures on the Stability of Calcined Dolomite and Magnesite

Flue Dust and Dolomite.—Figures 1 and 2 show the effect of different calcining temperatures and fine grinding on the tendency of flue dust-dolomite mixtures to increase in weight upon storage. It is evident that grinding the dolomite to 100 mesh size before calcination decreases its tendency to increase in weight after calcination, when compared to results[1] obtained in dolomite which has been ground to 8 mesh size previous to calcination. For example, 8 mesh dolomite mixtures prepared with 15% flue dust increased in weight 7% at the end of 80 days after calcining at cone 18, whereas with 100 mesh dolomite, the same percentage mixture increased in weight only 0.9% at the end of 80 days after calcining to cones 14 and 20.

Raising the calcining temperatures increases the tendency of the calcine to increase in weight due principally to taking up moisture and CO_2. For example, the mixture prepared with 15% flue dust increased in weight 1.4% at the end of 150 days after calcining to cone 14, 2.9% after calcining to cone 20 and 3.9% after calcining to cone 26.

Figure 2 shows the effects of flue dust when mixed with 40 mesh dolomite and calcined to cone 26. Increasing the per cent flue dust decreases the tendency to increase in weight up to an addition of 10%. With 15% flue dust it has a tendency to increase in weight more than with 10%. Adding 25% again decreases the tendency to increase in weight and 30% again increases the tendency. A somewhat similar relation is obtained with the 100 mesh dolomite mixture (see figure 1) after calcining to cone 14, but when these mixtures are calcined to cones 20 and 26 increasing

[1] *Loc. cit.*, p. 295.

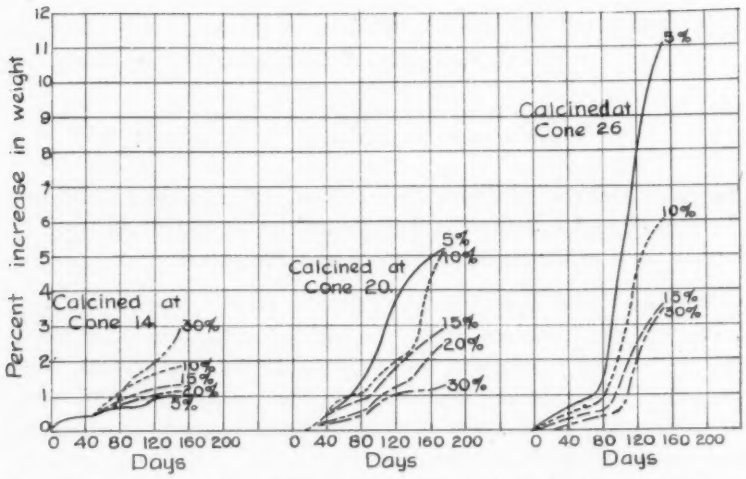

FIG. 1.—The effect of flue dust on the stability of dolomite after calcining at different temperatures. Dolomite and flue dust through 100 mesh.

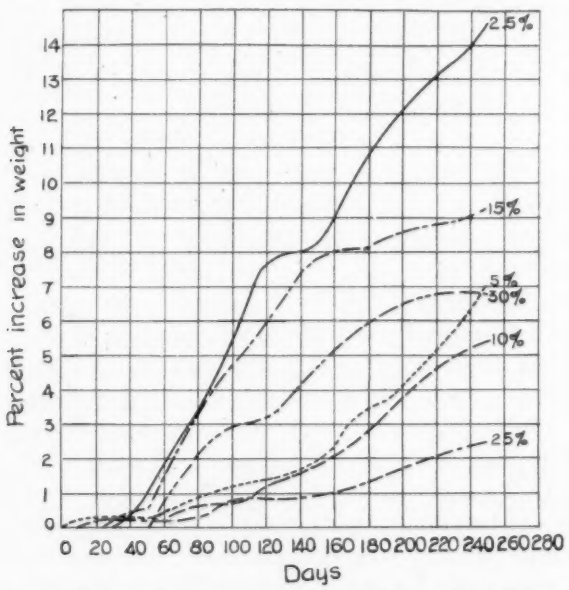

FIG. 2.—The effect of flue dust on the stability of dolomite after burning to cone 26. Dolomite through 40 mesh; flue dust through 20 mesh.

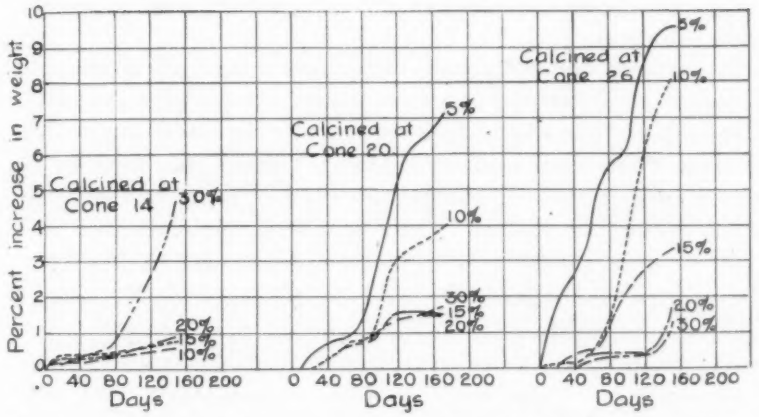

FIG. 3.—The effect of iron ore on the stability of dolomite after calcining at different temperatures. Dolomite and iron ore through 100 mesh.

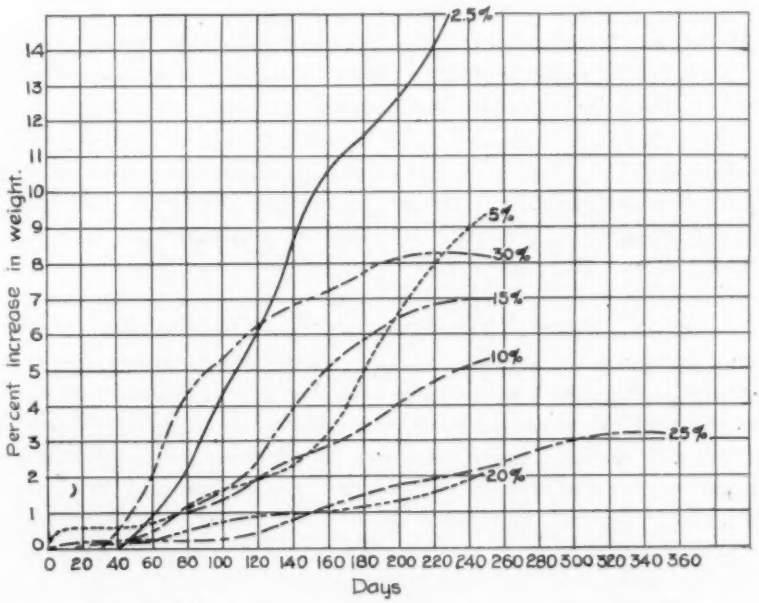

FIG. 4.—The effect of iron ore on the stability of dolomite after burning to cone 26. Dolomite through 40 mesh; iron ore through 20 mesh.

the flue dust content decreases the tendency to increase in weight upon storage.

It is evident that compounds which have a tendency to increase in weight when exposed to air are formed in calcined dolomite. Microscopic studies are now being made to determine the nature of these compounds and have already shown the presence of considerable $2CaO.SiO_2$, which evidently accounts for the disintegration due to dusting. Considerable uncombined iron was found as small globules of metallic iron together with free lime.

Iron Ore and Dolomite.—The results with iron ore and raw dolomite are shown in figures 3 and 4. Fine grinding of the raw dolomite again decreases the tendency to increase in weight during storage. Eight mesh dolomite prepared with 15% iron ore and calcined to cone 18, increased in weight 3% at the end of 80 days, while that prepared from 100 mesh dolomite and calcined to cone 20, increased in weight 1.5% at the end of 80 days. Increasing the calcination temperature again increases the tendency of the dolomite to take up moisture and CO_2. This agrees with the results obtained with flue dust and follows since flue dust and iron ore show similar chemical analyses.

Where dolomite is ground to 40 mesh size and calcined to cone 26 (see figure 4) it appears that increasing the iron oxide content up to 10% decreases the tendency to increase in weight. Adding 15% increases the tendency to take up moisture and CO_2 as compared to 10% mixtures. With a 20% addition decrease occurs, while adding 25% and 30% again increases the tendency to increase in weight. The effects produced by flue dust on 40 mesh dolomite are similar to those obtained with iron ore (see figure 2). Also, as was the case with flue dust, the mixture prepared from 100 mesh dolomite and calcined to cone 14 showed an increase in the tendency to take up moisture and CO_2 when prepared from mixtures high in iron ore. After calcining to cones 20 and 26, however, increasing the iron ore content decreases the tendency to increase in weight. These results also check with those obtained with flue dust (see figure 1).

Iron Ore and Magnesite.—Figure 5 shows the effects of different calcining temperatures on the increase in weight of

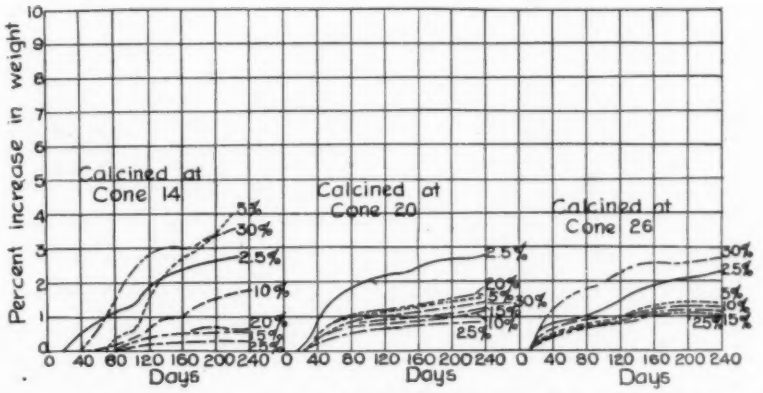

FIG. 5.—The effect of iron ore on the stability of magnesite after calcining at different temperatures. Magnesite and iron ore through 100 mesh.

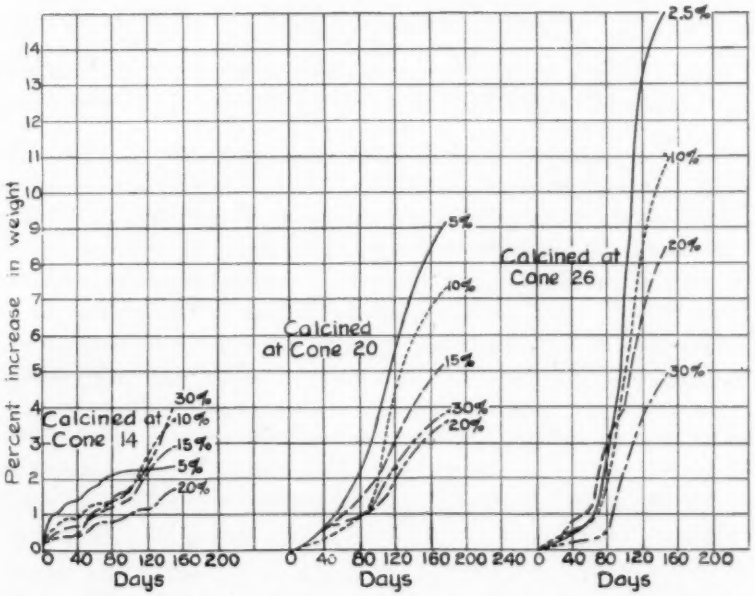

FIG. 6.—The effect of basic open-hearth slag on the stability of dolomite after calcining at different temperatures. Dolomite and slag through 100 mesh.

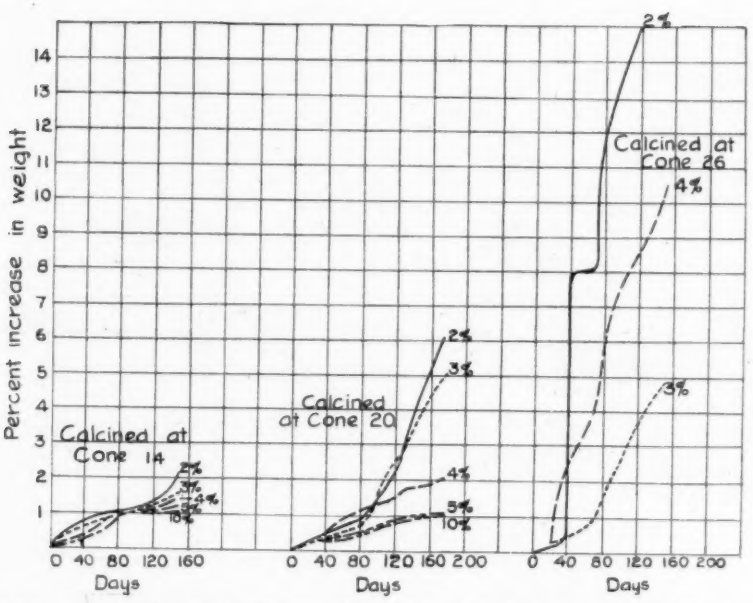

FIG. 7.—The effect of kaolin on the stability of dolomite after calcining at differen: temperatures. Dolomite and kaolin through 100 mesh.

Canadian magnesite and iron ore mixtures after storage. In most instances increasing the calcination temperature decreases the tendency of magnesite to increase in weight, although with those mixtures prepared from 15%, 20% and 25% iron ore, there is a slight increase in the tendency to take up moisture and CO_2 from the air after calcining at the higher temperatures. The magnesite employed contains 11% CaO. It shows a less tendency to slake than dolomite, due to the higher content of MgO which is comparatively easy to place in a dead burned condition. A mixture prepared from 10% iron ore with 100 mesh dolomite and calcined to cone 20 increased in weight 3.3% at the end of 160 days while the same percentage mixture with 100 mesh magnesite increased in weight only 0.85% which may be principally hygroscopic moisture.

Basic Open Hearth Slag and Dolomite.—Figure 6 shows the effects of fine grinding and different calcination temperatures

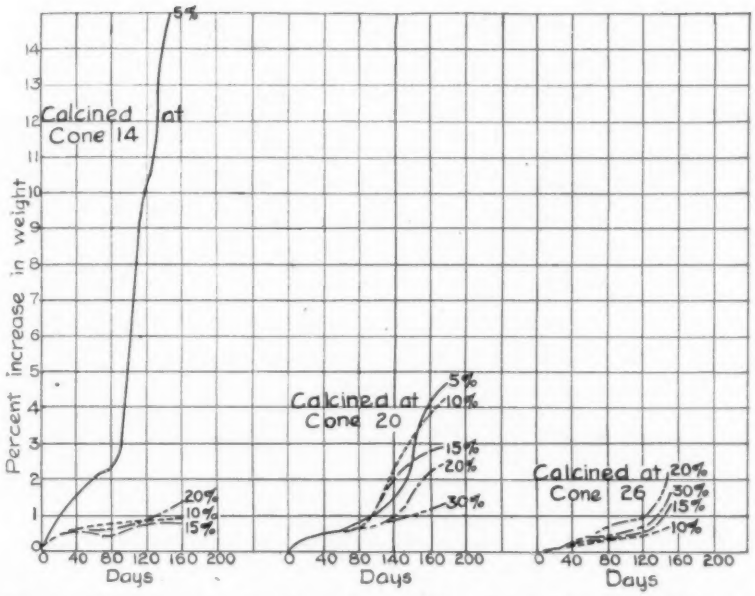

FIG. 8.—The effect of roll scale on the stability of dolomite after calcining at different temperatures. Dolomite and roll scale through 100 mesh.

on the tendency to increase in weight on storage. When a mixture prepared from 15% basic open hearth slag and 8 mesh dolomite is calcined to cone 18 it increases in weight 10.8% at the end of 80 days, whereas a similar mixture with 100 mesh dolomite, and calcined to cone 20 increases in weight only 1.4% in the same time interval.

Here again increasing the calcination temperatures increases the tendency of the calcined material to increase in weight. With basic open hearth slag as a flux, the high fired mixtures showed a greater tendency to increase in weight than with iron ore and flue dust as fluxes. This may be due to the lime and silica content of the slag which forms unstable compounds with the CaO of the dolomite.

Kaolin and Dolomite.—Figure 7 shows the effects of fine grinding and different calcination temperatures on the tendency of dolomite-kaolin mixtures to increase in weight. Increasing

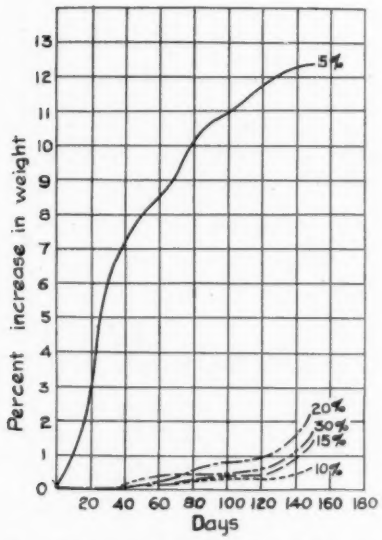

FIG. 9.—The effect of roll scale on the stability of dolomite after burning to cone 26. Dolomite through 40 mesh; roll scale through 20 mesh.

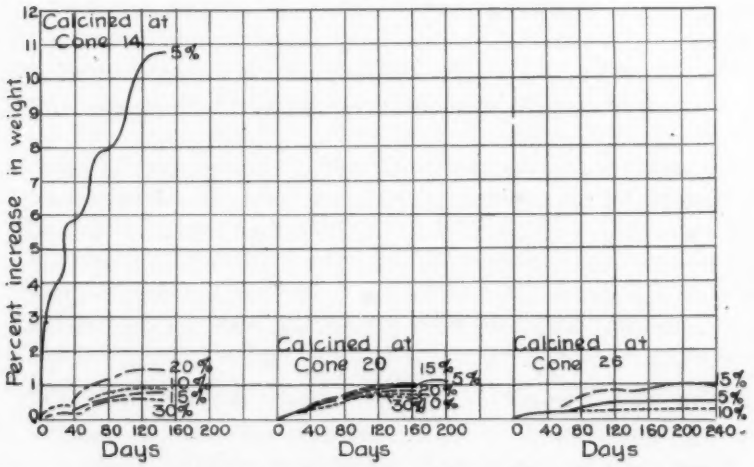

FIG. 10.—The effect of roll scale on the stability of magnesite after calcining at different temperatures. Magnesite and roll scale through 100 mesh.

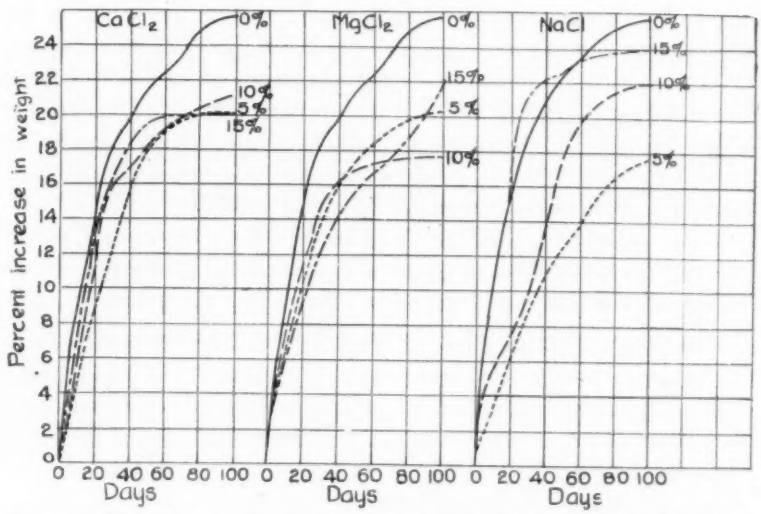

Fig. 11.—The effect of chlorides on the stability of dolomite after burning to cone 14. Dolomite through 8 mesh. Chloride through 20 mesh.

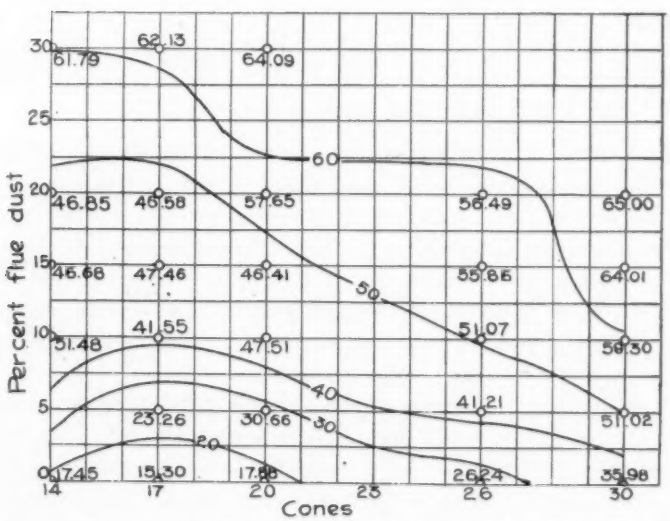

FIG. 12.—Burning, shrinkage, diagram. Dolomite—flue-dust mixtures.

the calcination temperatures again increases the tendency of the calcine to increase in weight. The increase in weight during storage is more pronounced on the high fired specimens than with the corresponding iron ore and flue dust mixtures. This is probably due to the comparatively high silica-alumina content of the kaolin which evidently forms hydraulic compounds with the lime similar to those found in Portland cement.

Finer grinding of the dolomite increases the resistance of the calcine towards moisture and CO_2, producing a more stable product than that obtained with coarser raw materials.

Roll Scale and Dolomite.—Figures 8 and 9 show the effects of calcination temperatures on the tendency of dolomite-roll scale mixtures to increase in weight. When mixtures of 15% roll scale and 8 mesh dolomite are calcined to cone 18, they increase in weight 5.5% at the end of 80 days[1] and where 100 mesh dolomite is employed with 15% roll scale and calcined to cone 20 the increase in weight is only 0.6% at the end of 80 days.

With roll scale, increasing the calcination temperature does not materially change the tendency of the product to take up moisture and CO_2.

Where the raw dolomite is screened through a 40 mesh sieve before mixing with roll scale and is calcined to cone 26, the mixture containing the highest per cent of roll scale increases in weight more than those containing a lower per cent.

Roll Scale and Magnesite.—Figure 10 shows the effects of varying percentages of roll scale and calcination temperatures on the tendency of roll scale magnesite mixtures to increase in weight during storage. Increasing the calcination temperature decreases the tendency to increase in weight. The comparatively small increase in weight of calcined magnesite mixtures as compared to calcined dolomite mixtures shows that calcined magnesite is much more stable than calcined dolomite.

In comparing the effects of roll scale on the slaking of magnesite to those of iron ore (see figure 5) it is obvious that the former is much more effective as a dead-burning agent for magnesite than the latter. This is probably due to the lower silica and

[1] *Loc. cit.*, p. 301.

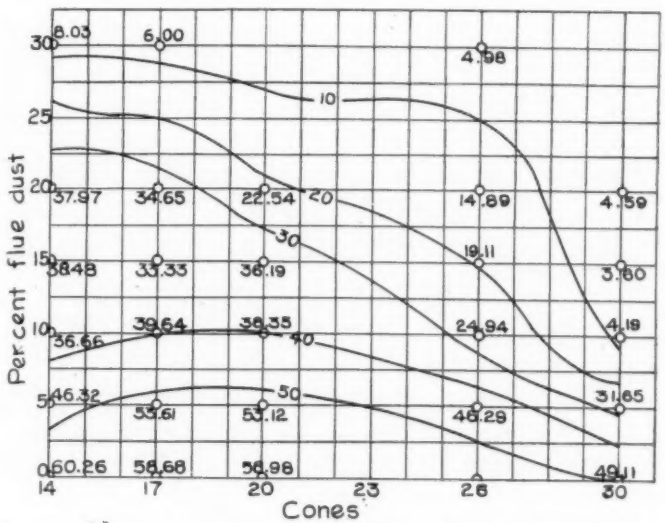

FIG. 13.—Burned porosity diagram. Dolomite—flue-dust mixtures.

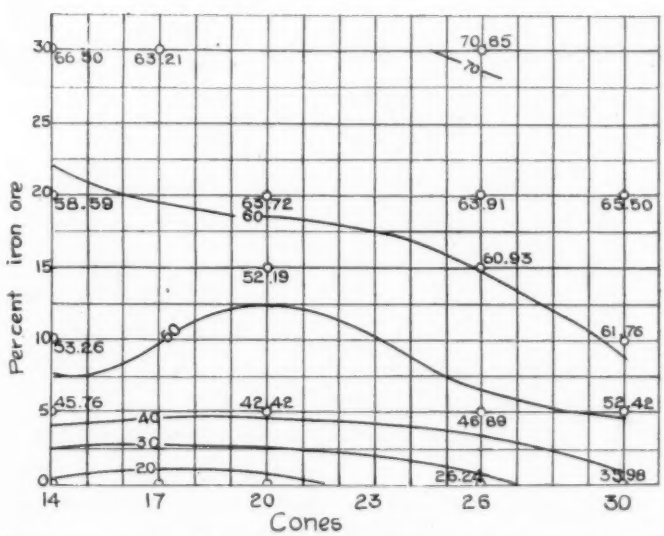

FIG. 14.—Volume, shrinkage, diagram. Dolomite iron-ore mixtures.

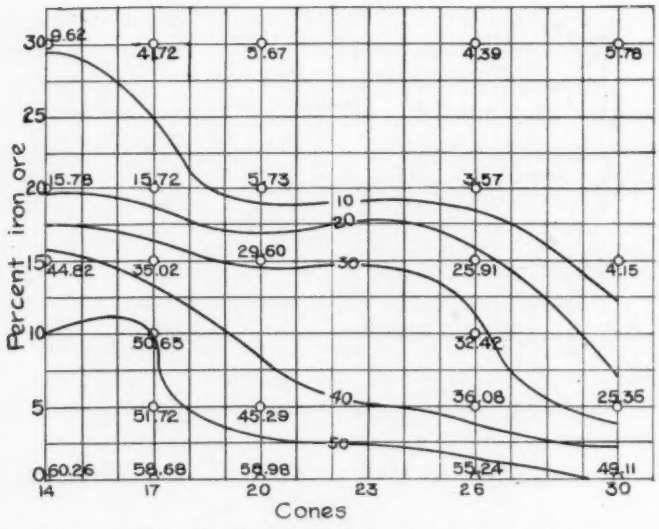

FIG. 15.—Porosity diagram. Dolomite—iron-ore mixtures.

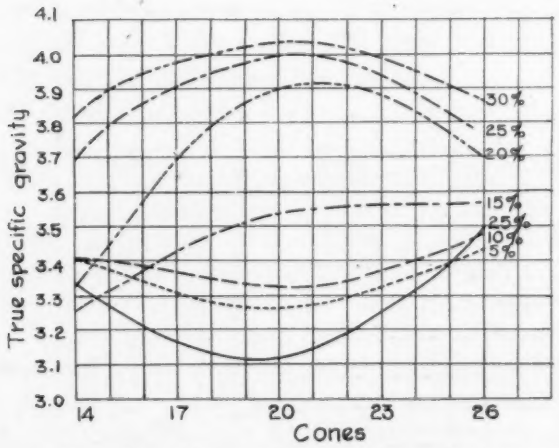

FIG. 16.—The effect of burning temperatures on the true specific gravity of dolomite and iron ore-mixtures.

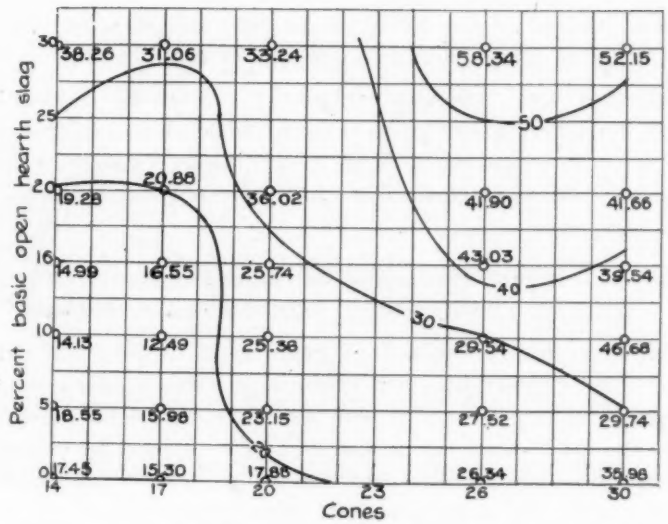

FIG. 17.—Volume shrinkage. Dolomite—basic open-hearth slag mixtures.

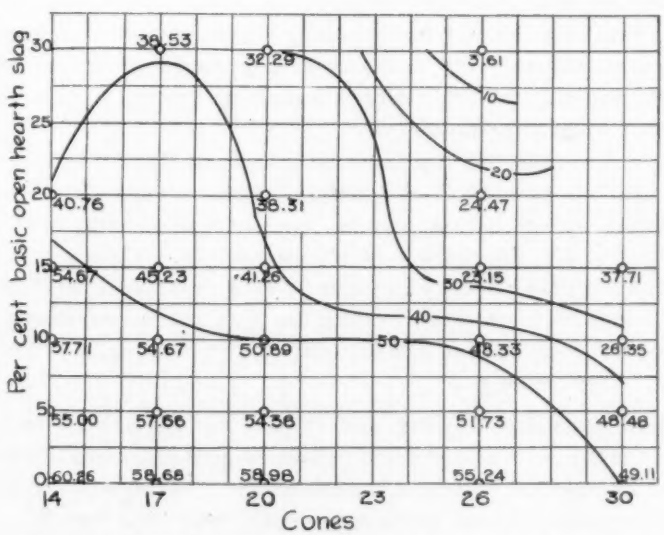

FIG. 18.—Burned porosity diagram. Dolomite—basic, open-hearth slag mixtures.

alumina content of the roll scale as silica and alumina tend to form unstable compounds with the lime of the magnesite.

Chlorides and Dolomite.—Figure 11 shows the results obtained by adding chlorides to 8 mesh dolomite and calcining to cone 14. Although the slaking is decreased to a slight extent, the benefits derived within the limits covered are too small to justify their use.

Effects of Different Fluxes and Calcining Temperatures on the Shrinkage and Porosity of Dolomite and Magnesite

Flue Dust and Dolomite.—Figures 12 and 13 show the effects of varying percentages and calcination temparatures on the shrinkage and porosity of the mixtures. To get maximum shrinkage and minimum porosity it is necessary to calcine a mixture of 30 per cent flue dust and 70 per cent raw dolomite to cones 14–20. It is necessary to calcine the mixture prepared with 25 per cent flue dust to cone 26 and the mixture with 10 per cent flue dust to cone 30 in order to obtain the same results.

Iron Ore and Dolomite.—Figures 14 and 15 show the effects of varying iron ore and temperatures of calcination on dolomite-iron ore mixtures. The behavior of iron ore is very similar to that of flue dust, which might be anticipated owing to their similarity in chemical analysis.

Figure 16 shows the true specific gravities of iron ore-dolomite mixtures when calcined at different temperatures. To obtain maximum specific gravity it is necessary to calcine mixtures with 2.5%, 5% and 10% iron ore to cone 26. That with 15% iron ore requires calcining to cones 20 or 26; and those with 20%, 25% and 30% to cone 20. When the high iron ore mixtures are calcined to cone 26, the specific gravity decreases, which may be due to over-burning.

Basic Open Hearth Slag and Dolomite.—Figures 17 and 18 show the effects of basic open hearth slag on dolomite mixtures when calcined at different temperatures. Vitrification is more dependent upon higher calcining temperatures than was the case with iron ore or flue dust. For example, a mixture containing 30 per cent basic open hearth slag must be calcined to cone 26

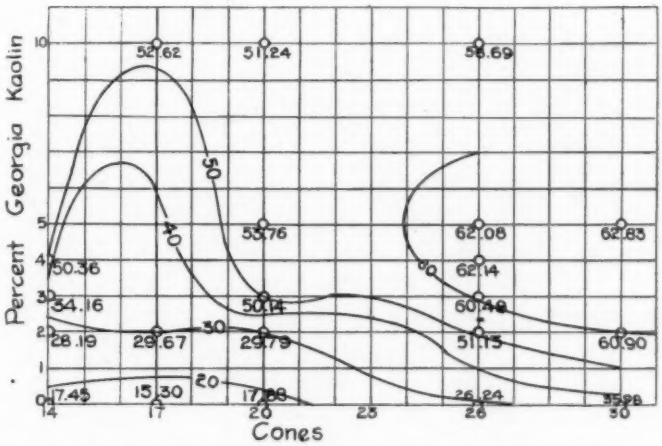

FIG. 19.—Volume shrinkage diagram. Dolomite—kaolin mixtures.

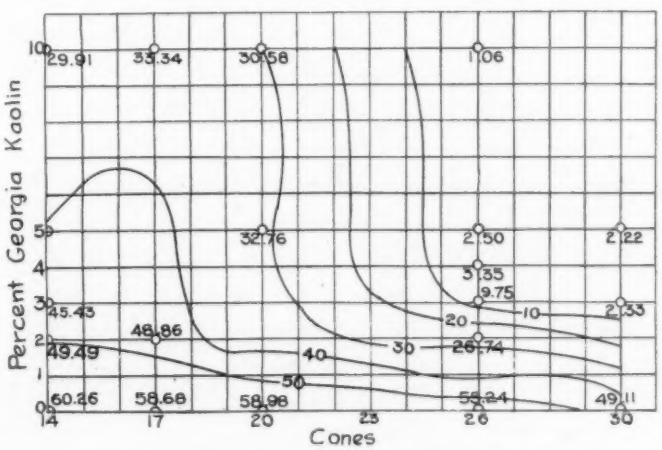

FIG. 20.—Porosity diagram. Dolomite—kaolin mixtures.

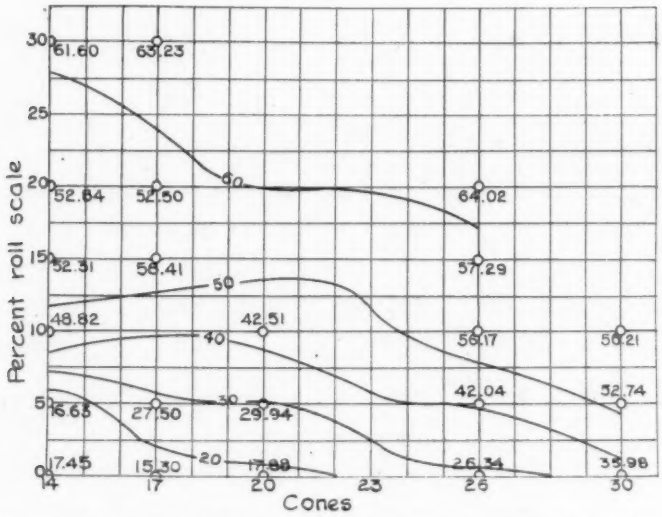

FIG. 21.—Volume shrinkage diagram. Dolomite—roll-scale mixtures.

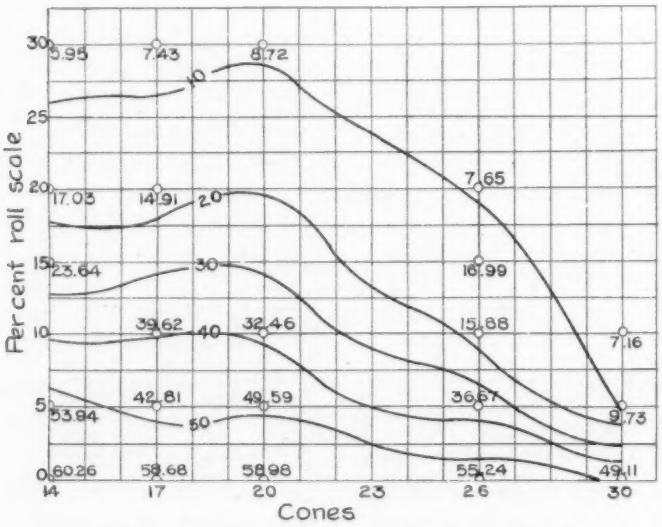

FIG. 22.—Porosity diagram. Dolomite—roll-scale mixtures.

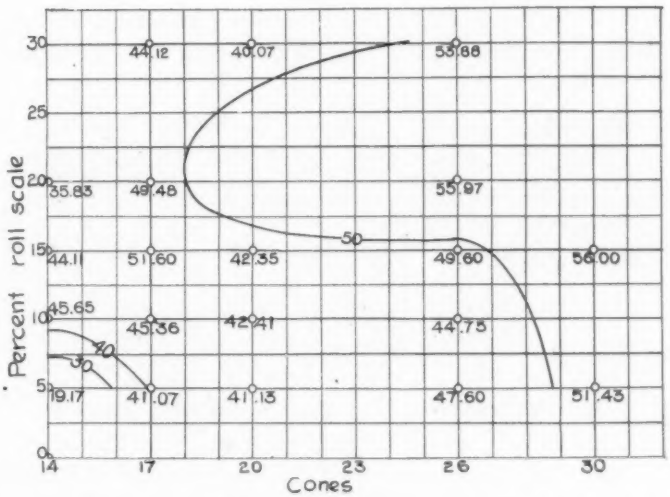

FIG. 23.—Burning, shrinkage, diagram. Magnesite—roll-scale mixtures.

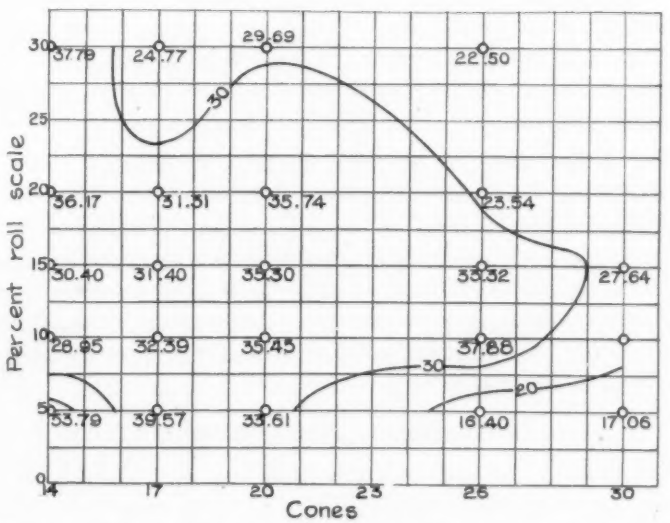

FIG. 24.—Burned porosity diagram. Magnesite—roll-scale mixtures.

to become vitrified, whereas a mixture containing 30 per cent iron ore or flue dust becomes vitrified at cone 14, (See figures 11, 12, 13 and 14).

Kaolin and Dolomite.—Figures 19 and 20 show the effects on shrinkage and porosity of Georgia kaolin and calcining temperatures on dolomite-kaolin mixtures. The vitrification is more dependent upon the calcining temperature than on the kaolin content when compared to flue dust and iron ore mixtures. Also kaolin is more effective than an equal weight of iron ore or flue dust in promoting vitrification. This is probably due to the higher silica content of the flux which combines readily with lime, forming lime silicates with a high per cent of lime, as $2CaO.SO_2$ and $3CaO.SiO_2$. For example, 5% kaolin and 95% dolomite has a porosity of 33.95% when calcined to cone 14 and is reduced to 2.50% porosity when calcined to cone 26, while a mixture of 5% flue dust and 95% dolomite has a porosity of 46.32% when calcined to cone 14 and 46.29% when calcined to cone 26.

Roll Scale and Dolomite.—Figures 21 and 22 show the effects of roll scale and calcining temperatures on the shrinkage and porosity of dolomite-roll scale mixtures. These diagrams are somewhat similar to those obtained with flue dust and iron ore. Bodies containing 30 per cent roll scale become vitrified at cones 14–20; those containing 20 per cent, at cone 26; and those containing 5–10 per cent are vitrified by calcining to cone 30.

Roll Scale and Magnesite. Figures 23 and 24 show the effects of roll scale and calcining temperatures on the shrinkage and porosity of magnesite-roll scale mixtures. It is seen that the shrinkage is much less and the porosity much greater with magnesite as compared to dolomite. The lime in the dolomite is more actively attacked by roll scale than the magnesia, which would account for the greater resistance of magnesite towards the corrosion of basic slags.

Results Obtained in Making Dolomite Brick

The mixtures of dolomite and iron ore were ground through a 100 mesh sieve and calcined to cone 20 in an air-gas furnace. As binders, one portion was mixed with 5% caustic lime, another

with 5% sodium silicate, and a third with 5% magnesium chloride. These batches were thoroughly pugged in a wet pan and brick were molded by hand. Upon drying, all of the brick cracked, due to slaking.

To overcome the cracking, the above batches were aged with an excess of water for at least three weeks. The ageing caused the batch to expand considerably due to slaking. Brick made from the aged material could be dried safely, since hydration had taken place, hence no cracking due to hydration occurred in drying. Those made with magnesium chloride were very strong on drying, due to the formation of Sorel cement.

When these brick were fired to cone 18 they, however, showed excessive cracking due to high shrinkage in firing. These brick were extremely dense and withstood storage from four to six months when they began to show disintegration due to air slaking.

The next series of brick were made with coal tar as a binder. The calcined dolomite was ground to pass a 40 mesh sieve and mixed while hot with 12% coal tar which had previously been dehydrated by heating to 200°C. The brick were formed while still hot under a pressure of 500 pounds per square inch. By selecting a tar which becomes hard on cooling, brick with sufficient mechanical strength to withstand handling and shipping may be made without burning. Tar-bonded brick will stand storage about four months, after which they begin to disintegrate.

The tar-bonded brick when fired show less shrinkage and cracking than those prepared with water, since no hydration has taken place. It is desirable to dip dolomite brick in tar as soon as taken from the kiln in order to prevent rapid disintegration. Brick made in this manner withstand storage five to six months before showing signs of disintegration.

In conclusion the writer wishes to acknowledge his indebtedness to Mr. R. T. Stull for assistance in this work.

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MINING EXPERIMENT STATION, COLUMBUS, OHIO

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

NORMAL CONSISTENCY OF SANDED GYPSUM PLASTER[1,2]

By W. E Emley and C. F. Faxon

ABSTRACT

Variation of tensile strength of sanded gypsum plasters with composition and consistency before setting.—To each of a series of 12 plasters, containing various proportions of sand, 5 different amounts of water were added. The consistencies, determined by means of a Southard viscosimeter, and the tensile strengths of the set plasters are tabulated. The results vary both with the kind of gypsum and with the fineness of the sand.

Suggested method of determining normal consistency of sanded gypsum plasters.—As a result of considerable experience the authors have reached the conclusion that material of the proper consistency to be used for plastering will show a slump of $^1/_2$ inch when tested in the Southard viscosimeter.

The Southard viscosimeter, which is used for measuring the consistency of gypsum plasters, is described in detail in the "Tentative Methods for Tests of Gypsum and Gypsum Products," published by the American Society for Testing Materials as No. C 26–19 T, in 1919. In this Tentative Method, it is stated that a mixture (of the sample and water) is of normal consistency if when tested by the Southard viscosimeter, it gives a circular patty averaging 9.7 cm in diameter.

This figure, 9.7, is purely empirical, but there are several good reasons for its adoption. The consistency does not vary directly with the amount of water: the relation between the two is probably logarithmic, as is the case in many similar relations. The particular consistency represented by the figure 9.7 is such that small variations in the amount of water make large variations in the consistency. This permits the normal consistency to be determined with a probable error of less than one per cent. From a practical viewpoint, this normal consistency may be stated to be about right for gypsum mortar or for reinforced gyp-

[1] Received September, 1920.

[2] Published by permission of Director, Bureau of Standards.

sum. It is possibly a little too thin for plaster. In this Tentative Method, no distinction is made between neat gypsum plasters and those containing sand.

During 1919, forty-three gypsum plaster were tested, in research work conducted by this Bureau.[1] Five of these samples were "ready mixed"—that is, they contained sand. It was found that a sanded plaster having the same consistency as a neat plaster when measured by the Southard viscosimeter, was in reality noticeably wetter. The above arguments in favor of the figure 9.7 no longer hold, and it was decided to establish a new figure for sanded plasters. At its 1920 meeting, the American Society for Testing Materials granted permission to revise the Tentative Methods to this effect. The Bureau of Standards was requested to develop sufficient data to be used as a basis for setting this new figure.

For this purpose the following program was carried out: Two kinds of calcined gypsum, and two kinds of sand were selected. Each gypsum was mixed with each sand, making four series. The proportions used were 1 : 1, 1 : 2 and 1 : 3 parts of gypsum by volume to parts of sand. This made 12 mixed plasters. Each plaster was tested at 5 different consistencies. The amount of water which could be added to make the material as dry as it could be worked and as wet as it could be worked, respectively, were found by trial and, in addition, three intermediate consistencies were used. The tests comprised noting the apparent consistency, measuring the consistency by means of the Southard viscosimeter, and measuring the tensile strength of the set plaster.

The results are shown in the following table:

PROPERTIES OF THE CALCINED GYPSUMS

	No. 1	No. 2
Chemical composition:		
Calcium oxide	35.72	38.90
Carbon dioxide	15.20	0.70
Sulphur trioxide	35.90	53.60
Loss on ignition	20.05	7.55
Calcined gypsum (calculated)	42.38	97.15
Normal consistency—cc water per 100 grams	44.6	61.0
Time of set	5 hrs. 37 m.	9 m.

[1] Physical Properties of Commercial Gypsum Plasters, by Emley and Faxon, THIS JOURNAL, December, 1920,

Fineness:		
Residue on No. 8 sieve, per cent	0	0
Through 8, retained on 14	0	0
Through 14, retained on 30	0	0
Through 30, retained on 50	1.7	0.3
Through 50, retained on 100	14.1	4.9
Through 100, retained on 200	10.3	13.2
Through 200	73.9	81.6
Yield:		
Lbs. paste per cu. ft	120	92
Lbs. dry material per cu. ft. paste	83	57
Lbs. set material per cu. ft	87	78
Strength, lbs. per sq. in.:		
Compressive	1400	1720
Tensile	129	270

SCREENING ANALYSES OF THE SANDS

Per cent retained on No. 14 sieve	0	0
Per cent passing No. 14 and retained on No. 30	16.0	0
Per cent passing No. 30 and retained on No. 50	46.7	46.9
Per cent passing No. 50 and retained on No. 100	22.9	40.0
Per cent passing No. 100 and retained on No. 200	6.5	8.5
Per cent passing No. 200 (by difference)	7.9	4.6

RESULTS OF TESTS

Gypsum No.	Sand No.	Proportions by volume	Cc water per 100 grams dry material	Apparent consistency	Consistency by Southard machine. Cms. diam. of pat.	Tensile strength, lbs. per sq. in.
1	1	1:1	22	stiff	no slump	119
			24	thick	8.8	97
			26.5	medium	12.5	82
			29	thin	15.5	72
			31	very thin	17	69
		1:2	18	stiff	no slump	90
			21	thick	bulged	69
			24	medium	10.7	53
			27	thin	15.6	41
			30	very thin	17.1	25
		1:3	19	stiff	no slump	30
			21	thick	bulged	31
			23	medium	9.7	17
			25	thin	13.4	11
1	2	1:1	23	stiff	no slump	104
			26	thick	bulged	86
			28	medium	10.0	79
			31	thin	12.9	79
			34	very thin	16.4	65

		1:2	20	stiff	no slump	48
			24	thick	bulged	33
			27	medium	9.8	29
			30	thin	14.7	30
			33	very thin	16.4	19
		1:3	17	stiff	no slump	44
			20.5	stiff	no slump	16
			24	thick	bulged	17
			27.5	medium	10.7	a
			30	thin	12.3	a
			31.3	thin	14.3	15
			32	thin	15.1	a
			33	very thin	16	a
2	1	1:1	12	stiff	no slump	240
			25	thick	bulged	74b
			28	medium	10	149
			32	thin	16.4	135
			34.5	very thin	18.1	130
		1:2	16.6	very stiff	no slump	a
			20	stiff	no slump	134
			22.3	thick	bulged	136
			24.6	medium	9.9	100
2	1	1:2	27	thin	13.5	96
			29.5	very thin	16.2	86
		1:3	17	very stiff	no slump	a
			21	thick	no slump	110
			24	medium	9.1	62
			27	thin	14.1	67
			30.6	very thin	16.8	60
2	2	1:1	22	stiff	no slump	223
			26	thick	bulged	266
			30	medium	11.9	182
			33	thin	14.4	153
			37	very thin	17.3	125
		1:2	20	stiff	no slump	128
			24	thick	bulged	92
			28	medium	10.9	102
			32	thin	16.7	92
			35.3	very thin	17.5	79
		1:3	20	stiff	no slump	56
			23	thick	bulged	63
			27	medium	8.8	56
			29.3	thin	14.4	54
			33.3	very thin	17.4	40

NOTES: All figures for tensile strength are the average of at least three determinations, usually of six, and sometimes of nine.

a.—These specimens were so weak that they could not be put in the machine.

b.—Evidently erroneous. Reason not known.

It must be confessed that the information contained in the above table is chiefly negative when considered as an answer to the question investigated. However, the intimate acquaintance with the Southard viscosimeter which has been gained in this research, and in the one cited above, does enable us to make a definite recommendation.

The Southard machine is designed to push the material vertically upwards out of a well, in such a way that it will overflow and spread out on a horizontal plate. This plate is graduated so that the final diameter of the pat can be measured. If the consistency of the material is very thin, the pat will tend to take the form of a plane. As the consistency is made thicker, through a comparatively long range, the final shape of the pat approximates the frustrum of a cone. The sides of this cone are concave instead of being straight, and they become more nearly vertical as the consistency becomes thicker. The "normal" consistency of 9.7 is near the thicker end of this range. If the consistency is a little thicker than 9.7, the material does not overflow on the plate. Instead, it bulges, so that its final form is that of a barrel. While the original diameter of the material as it comes from the well is such that it should be possible to get a reading of about 6 cm, we have never been able to get a reading much less than 9 cm. A material of such consistency that it should spread out to 7 cm diameter, for example will not spread at all, but will bulge instead.

As the consistency is made still thicker, the bulge becomes less pronounced, until finally it is not noticeable: the material retains the cylindrical form of the well. This is about the practical limit of consistency. Drier material is crumbly and can not be used.

The consistency used by plasterers is towards the thinner end of the bulging range. The graduations on the plate of the Southard viscosimeter can not be used to measure such a consistency. We can, however, have recourse to the "slump" method which was formerly used for measuring the consistency of concrete. We

can measure the decrease in the height of the specimen rather than its increase in diameter.

As a result of considerable experience, gained by using the Southard viscosimeter by five operators, during two years, on all kinds of plastering materials, it is our opinion that material of the proper consistency to be used for plastering will show a slump of $^1/_2$ inch when tested in this machine. That is, the final height of the specimen will be two inches. This applies to sanded plasters only, mixed ready for scratch or brown coat work. For the neat materials used for finish coats, the original figure of 9.7 cm is satisfactory.

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[1] The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of *Chemical Abstracts* by coöperative agreement.

General and Miscellaneous

1. **Belting for power transmission.** ERNEST D. WILSON. Mellon Institute. *Trans. Am. Inst. Chem. Eng.*, **11**, 237–48 (1918).—Methods of testing: h. p. slip and effective pull curves are given with a discussion.

JAMES R. WITHROW (C. A.)

2. **Silicate paints.** CH. COFFIGNIER. *Rev. chim. ind.*, **28**, 299–301 (1919).—The method used in the lab. of the technical section of the Artillery for the *analysis of fireproofing paints* with a base of Na silicate, is outlined. 1. The sample is extd. with warm H_2O and filtered on a tared paper. The residue is called pigment. 2. The filtrate is titrated to Me orange with 0.5 *N* HCl. The result is expressed as Na_2O. Addition of the equiv. amt. of SiO_2 gives the amt. of *Na silicate* present. 3. *Water* is detd. by difference. 4. The examn. of the pigment varies with its nature. T. G. PHILLIPS (C. A.)

3. **Asbestos in the paint industry.** G. B. HECKEL. *Asbestos*, **2**, 5–10 (1920); *Drugs, Oils and Paints*, **36**, 141–2 (1920).—G. gives the legitimate uses for inert or reinforcing pigments in paints, with particular attention to asbestiform pigments, derived from chrysotile. A fire-retardane paint for shingle roofs, adopted by the Natl. Lumber Manufs. Assoc., contains 33 per cent asbestine. F. A. WERTZ (C. A.)

4. **Talc in fire-resistant paint.** RAYMOND B. LADOO. *Drugs, Oils and Paints*, **36**, 144(1920).—Asbestine is not the chrysotile variety of asbestos but is a fibrous variety of talc. See preceding abstr. G. A. WERTZ (C. A.)

5. **Paints for iron which is exposed to high temperatures.** K. NICKSCH. *Z. Ger. Kohleus. Ind.*, **1919**; *Rev. chim. ind.*, **28**, 267 (1919).—Pure graphite is satisfactory for coatings of furnaces, autoclaves, etc., which are alternately heated and cooled. For good appearance and resistance to very high temps. sodium silicate has proved very efficient. Vessels subjected to even temps. may be protected by a hot application of a mixt. of 500 g. of melted lard and 16 g. of powdered camphor with enough pure powdered graphite to give a dark color. The excess which does not penetrate should be scraped off after 24 hrs. Cast-iron rust forms a coating which protects the body of the iron from further oxidation. Wrought iron forms no such protective rust but a covering with an iron oxide base, as red ochre, is resistant to acids and fumes at high temps. Walls of furnaces and chimneys where low temps. prevail may be painted with a thin coat of a pitch and tar mixt. which has been heated and to which 2 to 3 per cent of milk of lime and a little asphalt has been added. It may be dild. with turpentine. This makes a resistant coating which acquires an excellent luster. "*Durabo*" is a com. heat-resisting paint which must be preceded by a coat of red lead or iron oxide. Varnishes and drying paints can not be used, as they crack with temp. changes. Paints should be applied only to perfectly clean surfaces. Previous coats should be removed with 50 per cent carbolic acid soln. Rusted spots should be treated with 5 per cent HCl, followed by a rinsing with a dil. soda soln. After

thorough drying the surface should be polished with emery cloth or rottenstone. This thorough cleansing is very important. As base for the paint a thin coat of varnish or linseed oil may be applied. C. B. EDWARDS (C. A.)

BOOKS

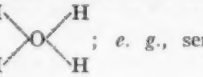
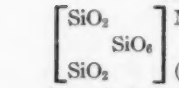
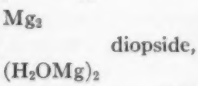
6. LACROIX, A.: **Les industries minérales non métalliféres a Madagascar.** Paris Editions de la Revue politique et littéraire. (C. A.)

Apparatus and Instruments

7. **The construction of thermocouples by electrodeposition.** WM. H. WILSON AND MISS T. D. EPPS. *Proc. Phys. Soc. London*, **32**, 326–40 (1920).—If a wire of constantan, or other metal of high resistance, is plated with a sufficient thickness of Cu or Ag, the plated portion becomes a compound wire whose thermal e. m. f. against the unplated portion is nearly as great as for the pure Cu or Ag. A plating from 25 to 35 per cent of the cross-section of the original wire is recommended. [The e. m. f. with constantan is then probably not over 14 per cent less than with pure Ag and constantan.—ABST.] By winding the original wire in a helix and plating one side of this, a series of plated and unplated pairs is obtained, forming a multiple-junction *thermel* (thermoelement). Very fine thermels can thus be made with very great ease. In one case a thermel of 4000 couples was made, whose hot end was less than 1.6 × 4 cm. W. P. WHITE (C. A.)

8. **The disappearing-filament type of optical pyrometer.** W. E. FORSYTHE. Nela Laboratory. *Trans. Faraday Soc.*, **15**, Pt. 3, 21–53 (1920).—A careful explanation, apparently intended especially for those not familiar with the instrument, and laying emphasis on its advantages. W. P. WHITE (C. A.)

Chemistry, Physics and Geology of Ceramic Raw Materials

9. **Constitution of the silicates.** JOHANN JAKOB. *Helvetica, Chim. Acta*, **3**, 669–704 (1920); cf. *C. A.* **14**, 917.—By a comprehensive comparative study of the transformation products of minerals their constitution is deduced. The silicates are here formulated according to the Werner principles. The prototype is considered to be $[SiO_6]R_8$ which dissociates easily at high temps. to coördinatively unsatd. penta- and tetra-oxysilicates which easily polymerize to higher forms, *e. g.*, asperolith, CuH_6SiO_6; chrysocolla, CuH_4SiO_5; dioptase, CuH_2SiO_4. Adjacent pairs of O atoms at the octahedron corners can add SiO_2 forming mono-, di- and tri-hexoxysilicates and pairs of H atoms in the outer sphere have residual affinity sufficient to hold water mols., forming the group ; *e. g.*, serpentine,  , deweylite,  ; diopside,  . The octahedral formulation predicts the possibility of optical isomers in the two latter cases.

Further SiO_2 groups can add upon 3,SiO_2 groups of $[(SiO_2)_3.SiO_6]R_8$ forming the types $[(O_2SiO_2)_2Si(O_2SiO_2SiO_2)]R_8$; $[(O_2SiO_2)Si(O_2SiO_2SiO_2)_2]R_8$ and $[Si(O_2SiO_2SiO_2)_3]R_8$. Al, Fe^{III}, Fe^{II} and Mg can act as central atoms of the octahedron and add SiO_6 octahedrons by common adjacent pairs of O atoms forming silicato-salts; *e. g.*, muscovite, $[Al(SiO_4)_3]Al_2KH_2$. Amphiboles are considered polymerized pyroxenes which are unstable except in water-rich magmas and by loss of secondary SiO_2 groups form olivine: $3\underset{\text{pyroxene}}{[(SiO_2)_3.SiO_6]}Mg_4 \rightleftharpoons \underset{\text{amphibole}}{[Mg((SiO_2)_3.SiO_6)_3]Mg_{11}} \rightleftharpoons \underset{\text{olivine}}{[Mg(SiO_6.SiO_2)_3]Mg_{11}} + 6SiO_2$. Tourmaline is formulated as $4[Al(SiO_4)_3]R_9 + 1\left[Al\begin{pmatrix}OBO\\O\\OBO\end{pmatrix}_3\right]Al_3$. Hydrolysis processes are discussed at length. A. R. MIDDLETON (C. A.)

10. Prosiloxan, the silicon compound corresponding to formaldehyde. A. STOCK. *Chem.-Ztg.*, **43**, 594 (1919).—HSiHO, prepd. by S. and C. Somieski by the action of water on SiH_2Cl_2, polymerizes rapidly to products similar to silicic acid; in the rapidity with which this occurs, and in its reducing properties, it is more active than HCHO. W. B. V. (C. A.)

11. Prolonged action of carbonic acid on silicates and quartz. C. MATIGNON AND (Mlle) MARCHAL. *Compt. rend.*, **170**, 1184–6 (1920).—Quartz, wollastonite, dioptase, mica, talc, asbestos, and glass, resp., in aq. suspension were submitted to the action of CO_2 under 10 atm. pressure for 10 years and 3 months. At the end of this time, all the *silicates* and the *quartz* itself were more or less *corroded*, and varying amts. of SiO_2 had passed into soln. Wollastonite showed the greatest signs of attack and the glass the least.
J. C. S. (C. A.)

12. Study of transition points by a dilatometric method. PAUL BRAESCO. *Ann. phys.* [9], **14**, 5–75 (1920); cf. *C. A.*, **14**, 876.—By a modification of Chevenard's differential method (*Rev. metal.*, **15**, (1917); cf. *C. A.*, **11**, 2743) giving the difference between the expansion of the sample and that of a standard substance, B. has detd. the temps. at which abrupt changes of vol. occur, the changes being due to changes of phase. For standard an alloy of Ni and Cr. (10 per cent Cr) was entirely suitable, as the expansion of the alloy shows no irregularities up to 1000° and as the transition point of Ni is much depressed (to —175°) by the 10 per cent Cr. Many of the materials being powders were made into compact form by compression and by the addition of 5 per cent of sodium silicate. The following results were found for SiO_2; amorphous silica by pptn. had no transition; quartz α changes to quartz β at 575°; cristobalite α to β at 235°; tridymite α to β at 110–115° and to γ at 145°; quartz and amorphous silica to cristobalite above 1400°; tridymite to cristobalite at 1600°; quartz to tridymite between 1300° and 1400°. Thus cristobalite is the stable form above 1600°, while below 1600° tridymite is stable and at low temps. quartz is the stable form. The mean coff. of expansion of quartz is 12×10^{-6} between 100° and 300°; 14×10^{-6} between

200° and 300°; and 21.3 × 10^{-6} between 300° and 500°. A study of *clays and clay constituents* showed the following: The expansion of mica is regular up to 900°; natural clays show a decided break in their expansion at temps. from 630° to 840°, depending on the particular clay; kaolinite, however, showed a max. expansion at 500°, which confirms the work of Wallach (*C. A.*, **7**, 3647), who attributes the effect to dehydration of $2SiO_2.Al_2O_3.3H_2O$. Numerous expts. with metals and alloys are also described.

JAMES M. BELL (C. A.)

13. Bauxite as a pigment. A. COBENZL. *Farben-Ztg.*, **25**, 20 (1919).—The *blue* color of *bauxite* is due to FeS in an easy oxidizable colloidal form, and the $Al(OH)_3$ itself takes no part in the production of the color. A similar color may be observed in $BaSO_4$ that has stood for a long time in moist packages. In this case the org. matter in the water has reduced a little sulfate to sulfide, which has then been attacked by the acid present in the sample, and the liberated H_2S has reacted with the Fe compds. present with the production of colloidal FeS. J. S. C. I. (C. A.)

14. Bauxite as a pigment. M. RAGG. *Farben-Ztg.*, **25**, 151 (1919); cf. *C. A.*, **14**, 636.—R. agrees with Cobenzl (preceding abst.), that the *blue* color of *bauxite* is due to colloidal FeS. The occurrence of blue bauxite indicates that the mineral is composed of the residues from the soln. of aluminous limestones which have become mixed with org. material of animal and vegetable origin. The decompn. of the latter has then produced the H_2S required for the production of the blue color. J. S. C. I. (C. A.)

15. Perchloric acid as a dehydrating agent in the determination of silica. H. H. WILLARD AND W. E. CAKE. *J. Am. Chem. Soc.*, **42**, 2208–12 (1920).—The dehydrate of $HClO_4$ boils at 203° and at this temp. is a powerful dehydrating agent. Results are given for the estn. of SiO_2 in metals and alloys, limestone and sol. silicates showing apparent errors of only a few tenths of a mg. ALBERT SALATHE (C. A.)

16. An aid in the determination of silica. S. R. SCHOLES. *Chem. Analyst* **29**, 22–3 (1920).—Add a small amt. of Me-orange to the acid liquid before evapn. This serves as an indicator to ensure acidity, and dyes the gelatinous solid as it seps. from the soln. Every particle becomes colored and is less likely to be lost. H. M. LANCASTER (C. A.)

17. Opening up minerals with phosgene. CHARLES BASKERVILLE. *Science*, **50**, 443 (1919).—An abstract. The bleaching of the ferruginous siliceous bricks by the action of phosgene in plants where the poisonous gas was manufd. has been noted. The useful application of this method of conversion of Fe oxides into volatile $FeCl_3$, with a bleaching, for glass-sand, was suggested by Hulett. Phosgene under the influence of heat is very reactive at temps. of 450° and above. B. has converted oxides at Al and Ce, insol. in acids, oxides of Zr and Th, insol. in acids except boiling concd. H_2SO_4, directly into water-sol. chlorides or oxy-chlorides. Bauxite and carborundum yield ferric

and Al chlorides. Zr chloride has been distd. from zircon (silicate), $FeCl_3$ from the contaminating Fe being fractioned away due to its greater volatility. The silica remains behind. Thorianite yields sol. Th and U chlorides. The procedure is very simple. The pulverized material is heated in a quartz tube in a stream of gaseous phosgene. (Cf. Washburn and Libman, THIS JOURNAL, **3**, 635 (1920).) E. J. C. (C. A.)

18. Catalog of Swedish geological, paleontological, petrographic, and mineralogical literature for 1907–1917. FR. E. AHLANDER. *Geol. För. Förh.*, **41**, 539–606 (1919).—A list of titles, names of authors and references for about 1000 papers, arranged alphabetically by authors, published in Sweden and elsewhere. Many are in English, and some are chem. in nature.
W. SEGERBLOM (C. A.)

19. Chemical Composition of Post-Tertiary clay material. O. TAMM. *Geol. För. Förh.*, **41**, 462–8 (1919).—Analyses of clay from 4 different deposits in Sweden showed distinctly lower SiO_2 and higher Fe and Mg content than in the coarser layers. K. was often higher, Na lower, and Ca content variable. The Al content was always noticeably higher than the max. for the kaolinite formula, from 5 up to 12 per cent. W. S. (C. A.)

20. The origin of Flint. R. M. BRYDONE. *Geol. Mag.*, **57**, 401–4 (1920).—There are 3 kinds of flint: separate, interstratified continuous lines, and contrastified continuous lines (veins). The origin of these is discussed, a penecontemporaneous origin being advocated for the first 2, and a later origin for the veins. S. G. GORDON (C. A.)

21. Talc Mining in South Africa. ANON. *Eng. Min. J.*, **110**, 860.—A short résumé of a report by Trade Commissioner R. A. Lundquist in which production figures are given since the first production in 1913, and the various districts are very briefly described. The price of the crushed talc is given as £6, 5s. a ton and for uncrushed bulk talc as £3, 5s. f. o. b. Delago Bay.

22. Bauxite and aluminum in 1919. JAMES M. HILL. *Min. Res.*, **1919**, Pt. I, 33–40.—During the year 1919 the production of bauxite in the United States fell off 38 per cent from that of the preceding year, the entire decrease being in the Arkansas production, since the other districts showed a slight increase. Considerable bauxite was imported from South America, while a small amount was exported to Canada. Of the total production of 376,566 long tons a little less than 10 per cent was used by abrasive manufacturers and 0.25 per cent for the making of refractories. This is a decrease of 70 per cent in the amount used for abrasives due to an overstock accumulated during the war. The price of bauxite ranged from $5.45 to $10.00 a long ton with an average of $5.85 paid at the shipping point. Data are given on foreign production, with the exception of France, for the years 1915–1918. A list of bauxite consumers is given, also short descriptions of the principal districts in the United States and in foreign countries.

23. Thorium, zirconium, and rare earth minerals in 1919. WALDEMAR T. SCHALLER. *Min. Res.*, **1919**, Pt. II, 1–32.—The present report is essentially a reprint of the report for 1916 with the data brought up to date as far as is possible. The two Zr minerals zircon and baddeleyite or brazilite are described. The former has a quite general distribution in pegmatites. The United States localities are N. C., Fla., Va., N. J. and Okla. Baddeleyite is found in commercial quantities only in Brazil. The extraction of Zr from zircon is so difficult that deposits of zircon are of little value so long as there are deposits of the oxide baddeleyite. In consequence of this there has been no production of zircon in the United States since 1911, the entire supply of Zr ore coming from Brazil, mainly in the form of the oxide. A possible use of the metal Zr is in the mfg. of alloys, with nickel or iron for machine tools. This utilization has not yet reached the commercial stage. Various other methods of using Zr have been suggested but at the present the chief use is as a refractory in the form of the oxide. A synopsis is given of the uses of Zr, also production figures for the years 1902 to 1916. Data are not available since the latter date. D. D. SMYTHE.

24. The mining industry in North Carolina during 1913–1917. JOSEPH HYDE PRATT AND MISS H. M. BERRY. *Econ. Paper* No. **49**. N. C. Geol. and Econ. Survey. This paper gives a general survey of the mining and mineral industry of the state, only a portion of which is abs. here. *Abrasives.*—North Carolina is better supplied with corundum than any other state in the Union. Com. quan. are found only in 4 counties, though 60 localities are known. The production has been quite interrupted and, except for the year 1917, quite small. Garnet is mined but little, owing to the distance of the deposits from the railroad. Of that quantity some is used after being ground, while some is quarried massive and used for millstones. *Barite* occurs in a few localities and in 1917 was being mined by only three companies. The value of their product for that year was $5,080. *Talc.*—Deposits of this mineral occur in the western part of the state. Pyrophyllite is also mined and sold as talc but is inferior in quality to the true talc. Little of this talc is sold in the crude state, so no production figures are available except for the manufactured product. The yearly production for the last 20 yrs. has varied from about 2000 to 6,000 short tons. *Feldspar* was first produced in this state in 1911, at which time N. C. ranked 6th in quantity produced. The output steadily increased till in 1917 N. C. ranked first in quantity and second in value of feldspar produced. The feldspar is orthoclase or potash feldspar and is obtained from granite pegmatite dikes. Much of the product is ground at Erwin, Tenn., while the remainder goes to mills in O. and N. J. *Glass sand* has not been marketed from this state as yet, but there are deposits which could undoubtedly be used for this purpose. *Clays.*—With the exception of the kaolin, which is all shipped out of the state raw, most of the clays are manufd. before being placed on the market. The kaolin produced in 1917 had a value of $182,176 and the manufactured product for the same yr., mainly common brick, a value of $1,662,307. The results of a number of

tests of N. C. clays are given, also a short description of the value and uses of kaolin and other clays. D. D. SMYTHE.

25. Graphite. BENJAMIN L. MILLER. *Mineral Ind.*, **28**, 314–28 (1919).—A review of the industry in the United States and foreign countries. A. B. (C. A.)

26. Gypsum. FRANK A. WILDER. *Mineral Ind.*, **28**, 329–36 (1919).—Production and utilization are discussed. A. B. (C. A.)

27. Magnesite. SAMUEL H. DOLBEAR. *Mineral Ind*, **28**, 433–41 (1919).—Production and trade in the United States and foreign countries are discussed, with bibliography. A. B. (C. A.)

28. Mica. J. VOLNEY LEWIS. *Mineral Ind.*, **28**, 461 (1919).—A review, with statistics. A. B. (C. A.)

29. Talc and soapstone. FREDERICK B. PECK. *Mineral Ind.*, **28**, 656–63 (1919).—Production and imports are given and the use discussed. A. B. (C. A.)

30. Titanium and zirconium. ANON. *Mineral Ind.*, **28**, 685–7 (1919).—A review of the industries. A. B. (C. A.)

BOOKS

31. CLIBBENS, D. A.: **The Principles of the Phase Theory.** London: Macmillan & Co., Ltd. 382 pp. 25s. (C. A.)

Refractories and Furnaces

32. Physical characteristics of specialized refractories. III. Electrical resistivity at high temperatures. M. L. HARTMANN, A. P. SULLIVAN AND D. E. ALLEN. *Trans. Am. Electrochem. Soc.*, **38** (preprint) (1920); *Chem. Met. Eng.*, **23**, 721 (1920).—Curves and data are given showing elec. resistivities of 9 commercial refractories at temps. up to 1500°. Results are necessarily only approx. CHARLES HECKER (C. A.)

33. Fused silica; its properties and a few of its uses. STEPHEN L. TYLER. *Trans. Am. Inst. Chem. Eng.*, **11**, 189–202 (1918).—The history of development of this manuf. is given. The use of fused SiO_2 in cascade concentrators for H_2SO_4 is discussed. It is not suitable for H_3PO_4. Prospective development in spark-plug insulators is discussed. JAMES R. WITHROW (C. A.)

34. Core baking in electrically heated ovens. JESSE L. JONES. *Metal Ind.*, **18**, 450–1 (1920).—Details of construction of the furnace and thermo-regulator, capable of holding within 5° any temp. between 150 and 1450°F are not given. Comparative tests were made between the electrically heated oven and others heated with gas or oil. The binder was a mixture of linseed and mineral oils with or without dextrin. The cores were baked at 300 to 450°F. The results obtained were in favor of the elec. furnace as follows: (1) Oven temp. uniform throughout; (2) temp. held steady within 5°; (3)

no annoyance from fuel combustion products; (4) cores well baked in one hour at 450°F; (5) cores 50 to 200 per cent stronger, when tested by compression; (6) cores may be baked much faster; (7) about 1 kw.-hr. of elec. power required for 12 lb. of green cores. J. O. HANDY (C. A.)

35. **The measurement of physical properties at high temperatures.** A. GEORGE TARRANT. *Trans. Farraday Soc.* **15,** Pt. 3, 83–97 (1920).—See *C. A.*, **14,** 1018. It was found that *breaks in the carbon spiral of an elec. resistance furnace* could be easily and completely repaired by heating the break by passing current and applying a mixt. of graphite and synthetic resin, which flowed into the hot crack and subsequently became carbonized. W. P. WHITE (C. A.)

36. **A laboratory high-temperature coke-resistance electric furnace.** W. F. MUNN. *Chem. Met. Eng.*, **23,** 345 (1920).—Temp. of over 1800° can be readily and quickly obtained. The max. temp., 2300°, was attained in 20 min. from a cold start. The furnace body is built of silocel brick, 9 × 2.5 × 4.5 in.; electrodes are 1 in. diam. graphite; and a graphite crucible 1.25 in. in diam. The space between the crucible and electrodes is filled with granular coke. The transformer has 8 sep. connecting taps, giving a range of 20.7 v. to 38 v., 65 to 120 amps. The cost of operation does not exceed 30 cts. per hr. with power at 10 cts. per kw.-hr. C. A. FLORTING (C. A.)

37. **Relative thermal economy of electric and fuel-fired furnaces.** E. F. COLLINS. *Gen. Elec. Rev.*, **23,** 768–73(1920).—C. gives an elaborate table of the power cost and per cent heat available for coke, oil, natural and city gas, anthracite, bituminous coal, and electricity, at 200, 875, 1250, and 1550°, *i. e.*, the usual temps. for baking heat-treating, forging, and melting. The thermal efficiency of a furnace decreases rapidly with rising temp., due to radiation losses, and also much more in the fuel-fired due to heating up of air for combustion, a 50 per cent excess over theoretical generally being required. Only large installations are designed to recover this heat from the flue gases. Since the cost of combustible fuels is rising more rapidly than elec. rates, the cost per B.t.u. is coming to favor the latter. But already the increased output and improvement in quality from elec. equipment have resulted in considerable reduction in manuf. costs. Examples of the rapidly increased use of elec. heating are ovens for baking cores, japan, and enamel, for annealing, hardening, and carbonizing, and furnaces for practically all brass melting. F. H. HOTCHKISS (C. A.)

38. **Recent developments in furnaces for solid fuels.** PRADEL. *Feuerungstechnik*, **9,** No. 2, 13–17 (Oct., 1920).—Review of German patents, with 10 figures. C. J. WEST (C. A.)

39. **Coal saving in the chemical industry.** DAVID BROWNLIE. *Chem. Trade J.*, **67,** 247–50, 311–4, 343–5 (1920).—A report of conclusions based on personal inspection of 60 typical steam-boiler plants of chemical industries of Great Britain. The av. net efficiency of the boiler plants in question is only

58 per cent; by reorganizing them along modern scientific lines it may be raised to 75 per cent with a consequent saving of 23 per cent in the coal bill. Faults pointed out are (1) improper design of grates; (2) ignorance of heating value of coal used; (3) lack of records of water evapn.; (4) improper treatment of feed water, with resultant scale troubles; (5) failure to use economizers, CO_2 recorders and superheaters. In addition chimney drafts and steam jets are used where mechanical draft should be employed, brick work and pipe covering are defective and firing is poor. As to the cause, "the chief engineer of many chemical plants is merely a glorified mechanic without scientific experience or education, paid and treated accordingly."

H. L. OLIN (C. A.)

40. A new material for crucibles. ANON. *Brit. Clayworker*, **29**, 204 (1920). —The new bodies are made by adding bituminous or oil shale to clay. Other material containing volatile carbon which is decomposed upon heating may be used. Such a mixt. is embedded in oil shale or coke to maintain reducing conditions and baked at 700°–800°C. If the product is then fired to 1600° C it becomes hard and resist. to acids resembling carborundum and may be ground and used as an abrasive. Biscuit ware may be saturated with liquid hydrocarbons and fired under reducing conditions so as to produce a similar product. The material differs from plumbago crucibles, carbon bricks, etc., inasmuch as the clay is saturated with minute particles of carbon. These particles may be sealed in the clay by firing until the necessary degree of vitrification has been reached, and by this means they may be completely protected from being burned away. This latter is a serious defect in some articles mfgd. from carbonaceous matter and clay. H. G. SCHURECHT

BOOKS

41. HERMANN, HUGO: **Elemente der Feuerungskunde.** Leipzig: Otto Spamer. M. 11, bound M. 16. For review see *Chem. App.*, **7**, 160 (1920). (C. A.)

42. JÜPTNER, H. v.: **Beiträge zur Feuerungstechnik. 1 Teil.** Leipzig: Arthur Felix. 189 pp. M. 10. (C. A.)

43. THOMAS, H. H., HALLIMOND, A. F., AND BRADLEY, E. G.: **Special Reports of the Mineral Resources of Great Britain. Vol. XVI. Refractory Materials, etc., Petrography and Chemistry.** London: H. M. Stationery Office. 5s. (C.A.)

Whiteware and Porcelain

44. Chemical stoneware. A. MALINOVZSKY. *Trans. Am. Inst. Chem. Eng.*, **11**, 103–18(1918).—The manuf. of chem. stoneware is a sep. and distinct branch of the ceramic industry which received great impetus in this country due to the war. Great care should be taken to produce a uniform body and skilled workmen are necessary. Lab. tests were made on the amt. of water absorbed, loss after being filled with 66° Bé. H_2SO_4 and boiled for 12 weeks and loss of wt. on treating powdered crucibles with nitric and sulfuric acids. The tests

showed less than 1 per cent absorption of water or loss of wt. Microscopic examns. have shown that in all cases, in the vitrified compn., the burning has produced enough fusion among the materials used in making the ware to develop a glass as in lavas. The very great importance of proper annealing is not understood by most manufacturers. Discussion by Whitaker says that it is very difficult to get proper resistance to acids, resistance to temp. changes and proper tensile strength of the burnt body combined in one piece of chem. stoneware, especially large pieces as compared to lab. size articles as discussed in this report. Tensile strength of the stoneware goes from 600 lbs. to a max. of over 2,000 pounds to the sq. in. Bebie remarked that European enameled ironware had an advantage over Am. material because the European material was enameled cast iron, whereas Am. is mostly enameled steel, which has more of a tendency to warp when exposed to changes in temp. whereby some of the enamel is chipped off. Malinovzsky states that if the stoneware body is attacked to the extent that it commences to dissolve 1.5 per cent the first half year, the dissolving action will increase more rapidly, with sometimes dangerous results to workmen. He also says that the success of the manuf. of chem. stoneware depends upon the material and its prepn., design and careful workmanship, and third on density, including strength. However, the strength is not proportional to the thickness. Failure is also produced in chem. stoneware by applying salt glaze. For surface protection feldspar glaze is best, it being under control and not attacked by alkalies or acids. JAMES R. WITHROW (C. A.)

45. Manufacture of spark plugs. ANON. *Clayworker*, 324–326 (1920).—The process used by the Champion Ignit. Co., at Flint, Mich., is described. 11 domestic clays are used in the mix. The mixt. is blundged, filter pressed and kneaded on a kneading table. A throwing mach. forces the clay through a small cylinder slightly larger than the plug, after which the plugs are baked in revolving ovens. The cylinders are then turned down to form seen in the finished Buick plugs. During the same operation the upper end of the insulator is threaded to take center wire. The forms are again sent to an oven where more moist. is driven off, after which they are glazed. The center wire is cut off in proper lengths and welded to the head that screws into the porcelain. The threads are then cemented and the center wire is screwed into place. The porcelain is again baked until cement is as hard as the porcelain. To insure against leaky plugs an asbestos gasket enclosed in a thin shell of copper is placed at the lower shoulder of the porcelain flange.

H. G. SCHURECHT

Glass

46. Dissolved gases in glass. EDWARD W. WASHBURN, FRANK F. FOOTITT AND ELMER N. BUNTING. Urbana, Ill. *Univ. of Ill. Eng. Expt. Sta. Bull.*, No. 118 (1921). The existence of dissolved gases in considerable quantity in a piece of perfectly clear barium flint optical glass was demonstrated by the method of "sudden evacuation." The glass was melted at atmos. pressure in

a vacuum furnace (figure). When the temp. reached about 1200°C the furnace was connected with a large evacuated tank. The furnace cooled under a pressure of less than 1 cm of mercury. On opening furnace most of the glass was found outside of the pot, in the form of a large white mass of foam (figure). The increase in volume of the mass was about 6 times that of the original piece. A special apparatus (figure) for both measuring and analyzing the dissolved gases was developed. The furnace consisted of a Pyrex glass tube 5 × 13 cm, with ground glass stopper, containing a porcelain melting pot wound with Pt wire. 25 or 50 g. of glass were introduced into the pot and after removal of adsorbed moisture the temp. was raised to 1400°C and maintained until manometer reading was steady. An Orsat app. was used to analyze the evolved gas for CO_2 and O_2 any residual gas being considered N_2. The accuracy of the chemical analysis was about 1 per cent. The three glasses investigated were; a barium flint optical, a light flint bulb, and a boro-silicate laboratory glass.

TABLE

	Volume per cent S. T. P.				Weight per cent				Concentration Moles per liter		
Glass	O_2	CO_2	N_2	Total	O_2	CO_2	N_2	Total	O_2	CO_2	N_2
Barium-flint (1)	83	27	1	110	0.035	0.011		0.046	0.033	0.011	
(2)	36	12	1	48	.015	.0045		.020	.016		
Light-flint	4.5	10	3	18	.0045	.014	0.0025	.021	.004	.010	.0003
Boro-silicate	6	5	6	17	.0036	.0035	.0031	.010	.0028	.002	.0028
Water at 0°C									.0023	.080	.0010

The quantity and nature of the gases present in finished glass obviously depends upon the batch composition and the melting and finishing procedures. It is not probable that any appreciable quantities of gas are absorbed from the furnace atmos. except possibly in the case of glasses which are stirred mechanically for a long period. The authors hint at possible applications in the construction of high vacuum scientific apparatus and technical operations in machines using the vacuum gathering principle. A vacuum furnace process for the manufacture of certain types of glass is possible on an industrial scale. It offers the advantages that the fining operation is eliminated, the finishing temp. reduced, and the product is free from even the smallest seeds. WM. M. CLARK.

BOOKS

47. SPRINGER, LUDWIG: **Laboratoriumsbuch für die Glasindustrie.** Verlag Halle, Wilhelm Knapp. 142 pp. M. 12, bound M. 14, 80 + 30 per cent. Verlagerzuschlag. For review see *Z. angew. Chem.*, **33**, II, 392 (1920). (C. A.)

Enamels

48. The enameled steel insdutry. WM. ZIMMERLI. *Trans. Am. Inst. Chem. Eng.*, **11**, 299–300 (1918).—Difficulties of the industry in war-time are discussed. JAMES R. WITHROW. (C. A.)

Cement, Lime and Plaster

49. Thermal phenomena in the setting of portland cement. F. KILLIG. *Concrete* (Mill Sec.), **17**, 120 (1920).—See *C. A.*, **14**, 3515.

J. A. MONTGOMERY.

50. Corrosion tests. ANON. *Concrete* (Mill Sec.), **17**, 126 (1920).—An investigation carried on by the National Lime Association gave results which indicate that lime can be used to advantage in gypsum construction for the purpose of preventing the corrosion of reinforcing steel.

J. A. MONTGOMERY.

51. Action of alkali soils and waters on concrete. A. S. DAWSON. *J. Eng. Inst. Canada*, **3**, 476–80 (1920); *Eng. Cont.*, **54**, 388–9 (1920).—Soap and $Al_2(SO_4)_3$ afforded some protection to concrete against alkali; however, soap reduced the tensile strength somewhat. The mixing of cement with weak solns. of H_2SO_4, Na_2HPO_4, MgF_2 and $(COOH)_2$ has been shown by lab. tests to increase the alkali-resisting qualities of concrete. According to D., the effects of most of the alkalies have also been shown to be less pronounced on neat cement briquets than on sand cement briquets, and in a degree proportional to the amt. of sand. J. A. MONTGOMERY.

52. A contribution to the dispersoid and colloid chemistry of plaster. I. WO. OSTWALD AND P. WOLSKI. Leipsig. *Kolloid-Z.*, **27**, 78–92 (1920).—The older theory of the setting of plaster, which attributes the process to the interlocking of needle-like crystals of $CaSO_4.2H_2O$ deposited from a supersatd. soln., can not account fully for the facts. A number of investigators have suggested that colloidal phenomena play a part, but have not been able to study the question because of the lack of a suitable method for following the kinetics of setting experimentally. O. and W. find that the observation of the change in viscosity of dil. suspensions of plaster with time after prepg. affords the desired exptl. method. The detns. were made in an Ostwald type viscosimeter. The viscosity-time curves are S-shaped, the viscosity rising slowly at first, then more rapidly, and finally becoming const. at its max. value. The time required to reach the max. measures the time of setting of the plaster. The concn. of suspension suitable for these expts. lies between 2 and 5 per cent. The higher the temp. the lower the max. viscosity. In one case the max. viscosity at 0° was 350 units, at 18°, 110 and at 60°, 23. Freshly ground plaster gives a higher viscosity than the same plaster after standing a few days. The dispersity of the plaster has an enormous influence, the finer the particles the higher the max. viscosity of the suspension. Added substances have an important influence. KCl causes the max. viscosity to be reached more quickly, but at a lower value. NH_4Cl gives a lower max. viscosity. With acetic acid the max. is reached more slowly, but is at least as high as the suspension with no addition. Further work is in progress.

F. L. BROWNE, (C. A.)

Books

53. TEDESCO, N. DE, AND FORESTIER, V.: **Nouveau manuel théorique et pratique du constructeur en ciment armé.** 2nd Ed. Paris: Cg. Beranher. 316 pp. For review see *Chimie & industrie*, **4**, 572 (1920). (C. A.)

54. The use of volcanic slag in concrete to save cement. H. SACHSE. *Tonind-Ztg.*, **44**, 831–833 (1920).—C. Platzmann (*Zement*, **19**, 227) used slag in the following proportions in concrete: 1 cement, ½ to 1 slag, and 4 to 11 silica. Also cement and fine sand mixtures were tested varying between the following limits: 1 cement and 7 to 11½ silica. The volcanic slag used had the following composition: SiO_2 56.4 per cent, Al_2O_3-Fe_2O_3 22.58 per cent, CaO 2.71 per cent, MgO 1.43, SO_3 trace, Na_2O-K_2O 77.94 per cent, Hygro. H_2O 2.83 per cent, Chem. H_2O 6.47 per cent. P. found that by using finely ground slag or sand together with cement the compress. strength is increased and less cement is required for concretes made with the same. Similar results can be obtained with finely ground brick dust or blast-furnace slag. By fine grinding, silicic acid is formed which combines with the free lime present in cements forming $CaSiO_3$. If no free lime is present, no bonding due to the silicic acid will result and the slag would tend to weaken the concrete since it would then simply act as an aggregate. S. suggests the addition of lime to cements together with finely ground slag thus obtaining the maximum bonding. H. G. SCHURECHT.

55. Plaster of Paris as putty. G. ATTERBERG. *Tonind.-Ztg.*, **44**, 871 (1920). —During the war numerous cements have been used as a substitute for putty which requires linseed oil. Most of these, however, were unsatisfactory in that the chemicals in the cement attacked the hands of the user. Plaster of Paris may be used in the place of these by adding sufficient lime to render the plaster slow setting. H. G. SCHURECHT.

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

January 19. It was voted to authorize Dr. Washburn to purchase a typewriter, with stand, for the Editor's office.

January 19. It was voted to send the JOURNAL OF THE AMERICAN CERAMIC SOCIETY for 1921 to Dr. Rieki, Dr. Pukall, and Dr. Endell, of Germany, in exchange for such scientific investigations as they may desire to send for publication in the JOURNAL.

January 27. It was voted to increase the number of copies of the JOURNAL printed monthly from 2200 to 2500.

January 27. It was voted to increase the subscription rate of the JOURNAL OF THE AMERICAN CERAMIC SOCIETY from six dollars to eight dollars a year.

Meeting of the Pittsburgh District Section of the American Ceramic Society

December 1, 1920

The Pittsburgh District Section held its last meeting of the year at the Mellon Institute on December 21, 1920.

Chairman Peregrine called the meeting to order at 2.15 P.M.

The committee on nominations submitted its report and on motion, duly seconded, the secretary was instructed to cast a unanimous ballot for the following officers:

Chairman, J. Spotts MacDowell, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Vice-Chairman, A. V. Bleininger, Homer Laughlin China Co., Newell, W. Va.

Secretary, J. W. Wright, Macbeth-Evans Glass Co., Charleroi, Pa.

Treasurer, Thomas H. Sant, John Sant and Sons Co., East Liverpool, Ohio.

Councilor, Francis W. Walker, Sr., Beaver Falls Art Tile Co., Beaver Falls, Pa.

The report of the treasurer was then submitted.

There being no further business the following papers were read:

"Properties of Commercial Gases," F. J. Denk, Consulting Mechanical, and Fuel Engineer, Pittsburgh, Pa.

"The Use of the Microscope in Ceramics," Dr. R. Thiessen, U. S. Bureau of Mines, Pittsburgh, Pa.

The paper by Mr. Denk prompted many questions of a practical nature from the members present. Dr. Thiessen presented the possibilities of the microscope in solving ceramic problems in a masterly way, and his paper interested all present.

C. C. VOGT, *Secretary.*

New Members received during January, 1921

Resident Associate

Anderson, John A., 299 Central St., Gardner, Mass., Central Oil and Gas Stove Co.

Bach, Julius H., 2647 Montrose Ave., Chicago, Ill., Bach Brick Company.

Bautz, Robert A., Murphysboro, Ill., Isco-Bautz Company, Inc.

Clark, Horace H., 325 Peoples Gas Bldg., Chicago, Ill., Fuel Engineer.

Dougherty, Robert H., National Lamp Works, Cleveland, Ohio, Assistant to Ceramic Engineer.

Grafton, C. V., Muncie, Ind., Treas. and Gen. Mgr., Muncie Clay Products Co.

Hail, Walter, Blackmer & Post Pipe Co., St. Louis, Mo.

Hart, L. H., 2800 Thirteenth St., N. W., Washington, D. C., Manager, Construction Dept., National Lime Association.

Kimberling, Henry P., Blackmer & Post Pipe Co., St. Louis, Mo.

King, Walter, A., Elyria Enameled Products Co., Elyria, Ohio, Assistant, Enamel Research Laboratory.

Manson, Mahlon E., Rundle Manufacturing Co., Milwaukee, Wis., Chemist.

Patten, D. M., Chattanooga Stamping and Enameling Co., Chattanooga, Tenn., Treasurer.

Reinecker, Haydn P., 145 Industrial Bldg., Bureau of Standards, Washington, D. C.

Shultz, J. Emmet, American Encaustic Tiling Co., Zanesville, Ohio, Modeler.

Turner, Eric W., Trenton Flint and Spar Company, Trenton, N. J.

Foreign Associate

Hawley, W. S., cr. George Howson & Sons, Ltd., Eastwood Sanitary Works, Hanley, Stoke-on-Trent, England, Managing Director.

Wang, C. Y., Rue de Paris, Extension, Hankow, China, Consulting Mining Engineer.

Corporation

Bach Brick Company, 2647 Montrose Ave., Chicago, Ill.

Chicago Crucible Company, 2525 Clybourn Ave., Chicago, Ill.

Russell Engineering Company, 1624 Railway Exchange Bldg., St. Louis, Mo.

Chicago Section

The ninth meeting of the Chicago Section of the American Ceramic Society was held at the City Club, 354 Plymouth Ct., February 5th, 1921.

The meeting was called to order by Mr. B. S. Radcliffe, chairman, with an attendance of 22.

After a delightful luncheon the following papers were read: "Notes on the Acid Resistance of Enameled Cooking Utensils" by B. T. Sweely. "Notes on the Manufacture of Lead Products Used in the Ceramic Industry" by Lester T. Wilson.

In the discussion on the first mentioned paper the cause of segregation of Borax or Boracic Acid in fritting enamels was brought up. In connection with Mr. Wilson's paper the fact was brought out that Lead Products used in the Ceramic Industry were purer than any other materials used.

AMERICAN CERAMIC SOCIETY

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Decorative Processes—Leon V. Solon, *Chairman*, Magnolia Ave., Tenafly, N. J.; Frederick H. Rhead, *Secretary*, American Encaustic Tiling Co., Zanesville, Ohio.

Enamels.—E. P. Poste, *Chairman*, Elyria Enameled Products Co., Elyria, O.; R. R. Danielson, *Secretary*, Bureau of Standards, Washington, D. C.

Glass.—S. R. Scholes, *Chairman*, Utility Glass Works, Lonaconing, Md.; E. W. Tillotson, *Secretary* Mellon Institute, Pittsburgh, Pa.

Refractories.—A. F. Greaves-Walker, *Chairman*, American Refractories Co., Pittsburgh, Pa.; R. M. Howe, *Secretary*, Mellon Institute, Pittsburgh, Pa.

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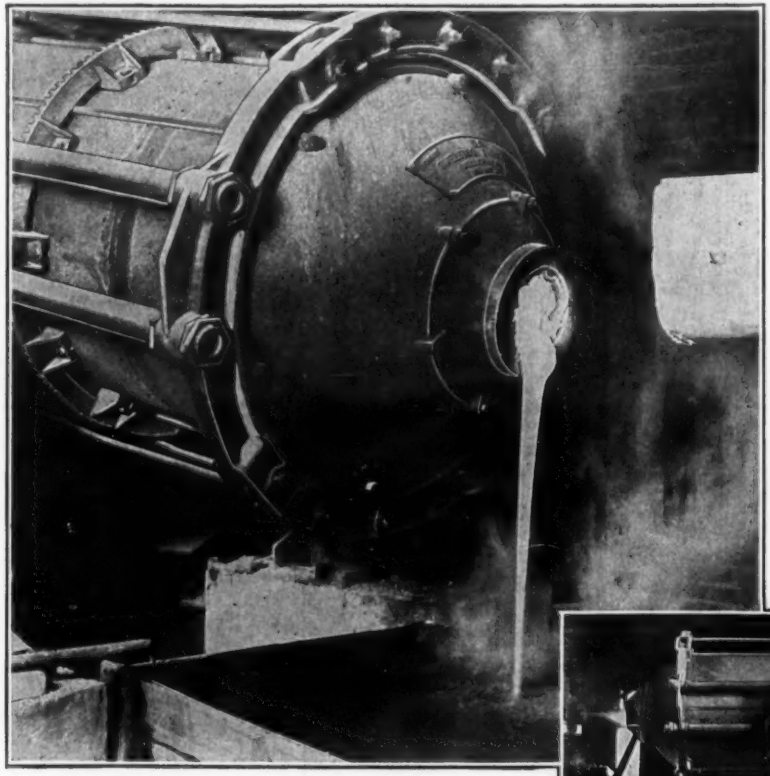

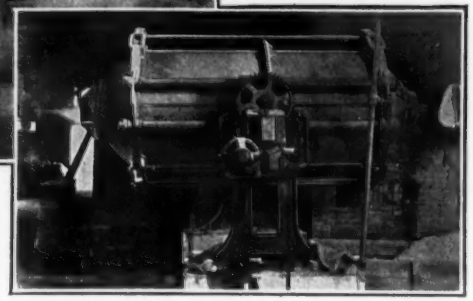

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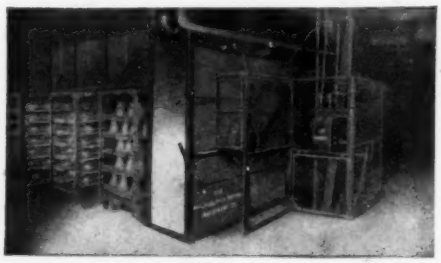

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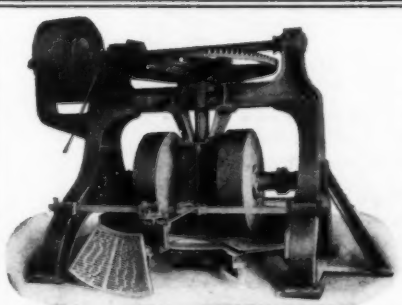

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